Water Power

INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

VOL. 13 FEBRUARY 1961

Photograph by courtesy of Snowy Mountains Hydro-Electric Authority

POWER

IN THE SNOWY MOUNTAINS

'ENGLISH ELECTRIC'

hydro-electric equipment

Four 'ENGLISH ELECTRIC' high-head Francis turbines and a spare runner have been supplied to the Tumut 1 Power Station, 1,200 feet below ground in the Snowy Mountains, Australia. These turbines, which can deliver 129,000 h.p. at 1,065 feet head, are amongst the most powerful at this head in the world.

'ENGLISH ELECTRIC' also supplied two 30,000 kW water turbine-alternator sets for the Guthega Power Station in the Snowy Mountains Scheme.

THE ENGLISH ELECTRIC COMPANY LIMITED, ENGLISH ELECTRIC HOUSE, STRAND, LONDON, W.C.2

Hydro-Electric Division, Dunnings Bridge Road, Netherton, Bootle, Liverpool, 10

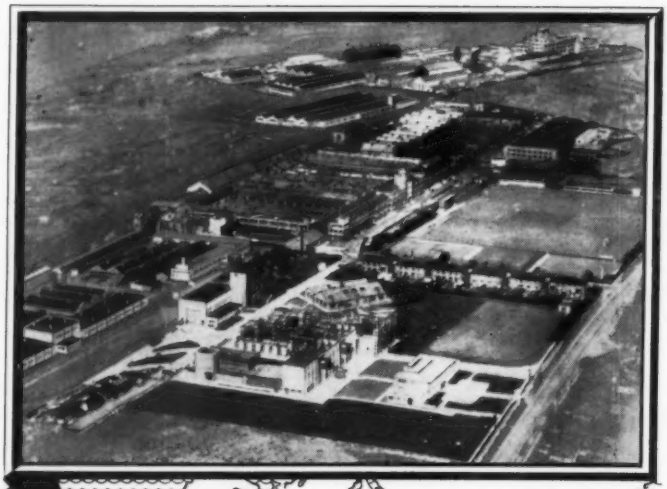
WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON

HEBBURN–

THE SOURCE

OF ELECTRICAL

SWITCHGEAR



* ***ENGINEERS AND REPRESENTATIVES AVAILABLE FOR CONSULTATION AND ADVICE***

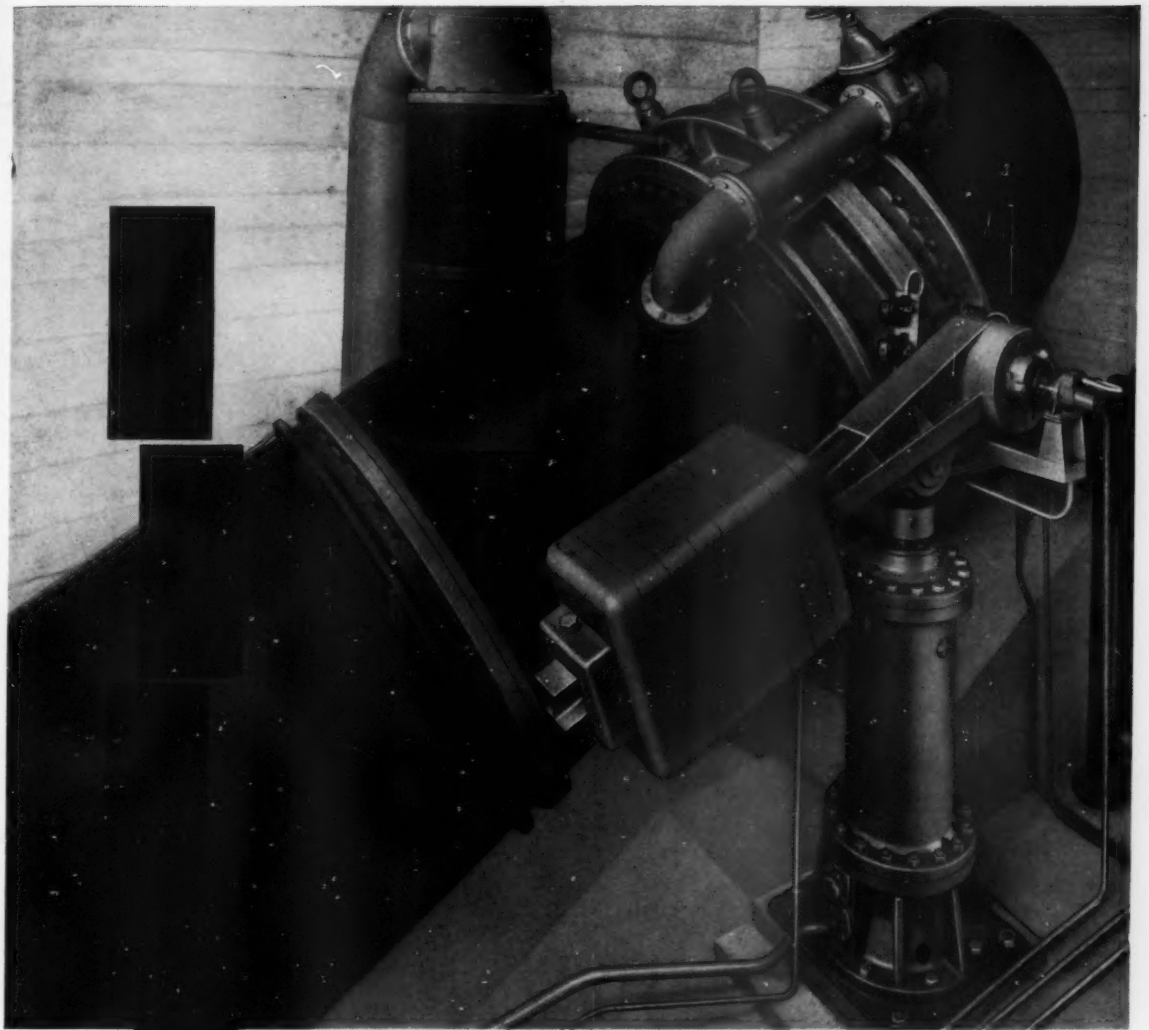
A WORLD-WIDE ORGANISATION

A WORLD-RENOWNED PRODUCT

REYROLLE

A MEMBER OF THE NUCLEAR POWER PLANT COMPANY LIMITED

A. REYROLLE & CO. LTD. HEBBURN COUNTY DURHAM ENGLAND



DE ROLL Butterfly Valve,
automatically shutting
in the event of penstock rupture,
at Ernen Power Station (Switzerland),
nominal diameter 1900 mm (75 in.),
working pressure 4,8 kg/cm² (68 psi),
with weight Drive for shutting
and oil-pressure operated Servomotor
for opening

322

This is the stone
that makes
the tower
stand or fall.
In a Power Station
it is the **Shut-off Valves**
that provide for the safety
of the entire plant
and thereby
make it stand or fall

DE ROLL

Shut-off Valves

our speciality

DE ROLL Iron Works, Klus (Switzerland)

"WOOD STAVE for HYDRO-ELECTRIC PIPELINES"

In rugged mountain and fertile valley this versatile conduit has demonstrated unparalleled economy and ease of construction.

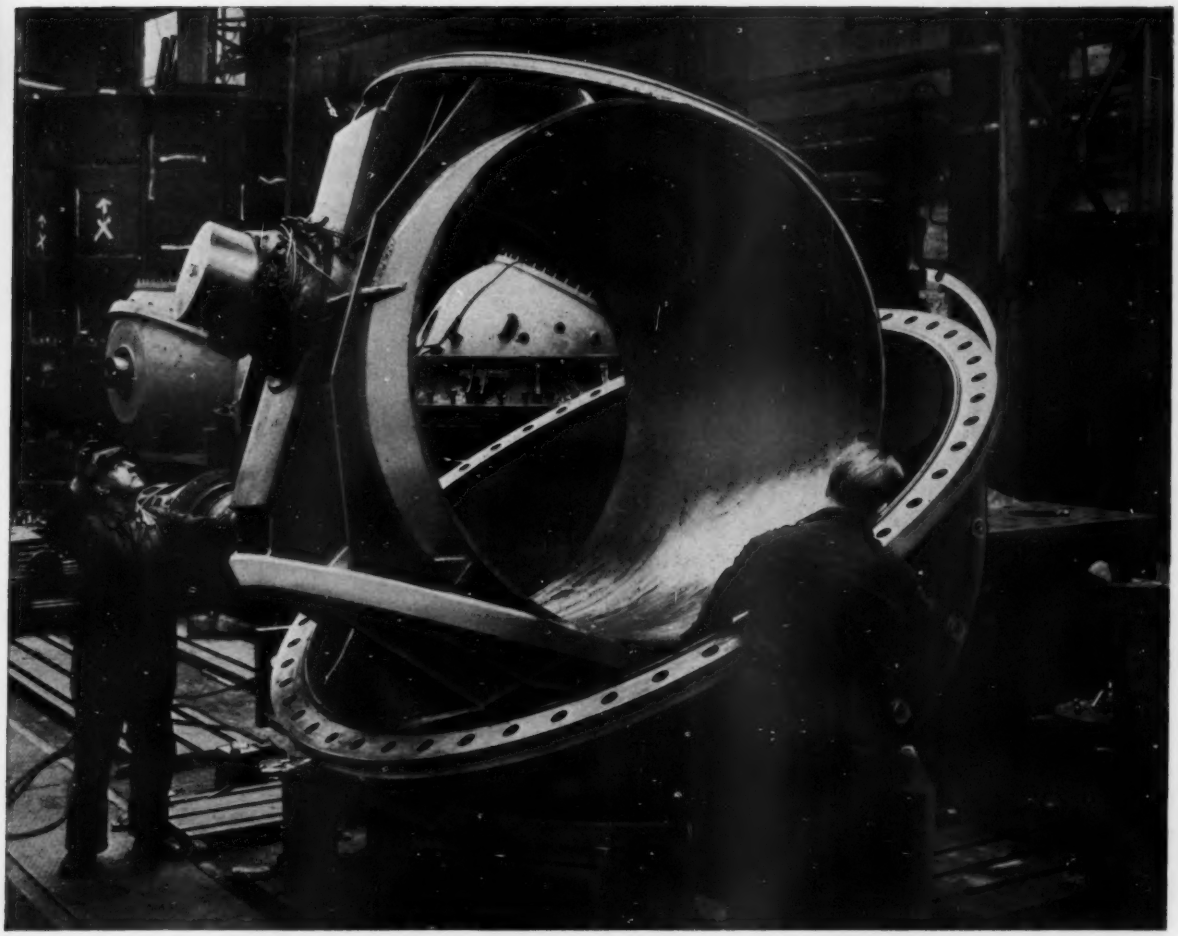
Wood stave pipe is assembled from manufactured components easily shipped to the most remote sites. It can be constructed over the most difficult terrain and complex contours by local labour. For these reasons, wood stave pipe is frequently the only economic solution available for penstocks, high-line conduits or irrigation projects.

Our recent publication: *CONTINUOUS STAVE WOOD PIPE*, reveals details of history, uses, construction and maintenance, together with design data and flow tables.

Write for your copy.

CANADIAN WOOD PIPE & TANKS LIMITED

550 Pacific Street,
Vancouver 2, British Columbia,
Canada



Boving robust design ensures

enduring efficiency

The illustration shows Boving Patent Rotary Valves in course of construction. These valves are used in high-head installations and are particularly notable for their —

SIMPLICITY · LOW HEAD LOSS · ROBUST DESIGN

Constant research into design and production methods, backed by the latest advances in technology, maintain Boving Quality at the highest standard. Simplicity and quality finish achieves increased reliability and reduces costly outages.

Boving
A CO LIMITED

VILLIERS HOUSE
41-47 STRAND LONDON WC2

P.4088

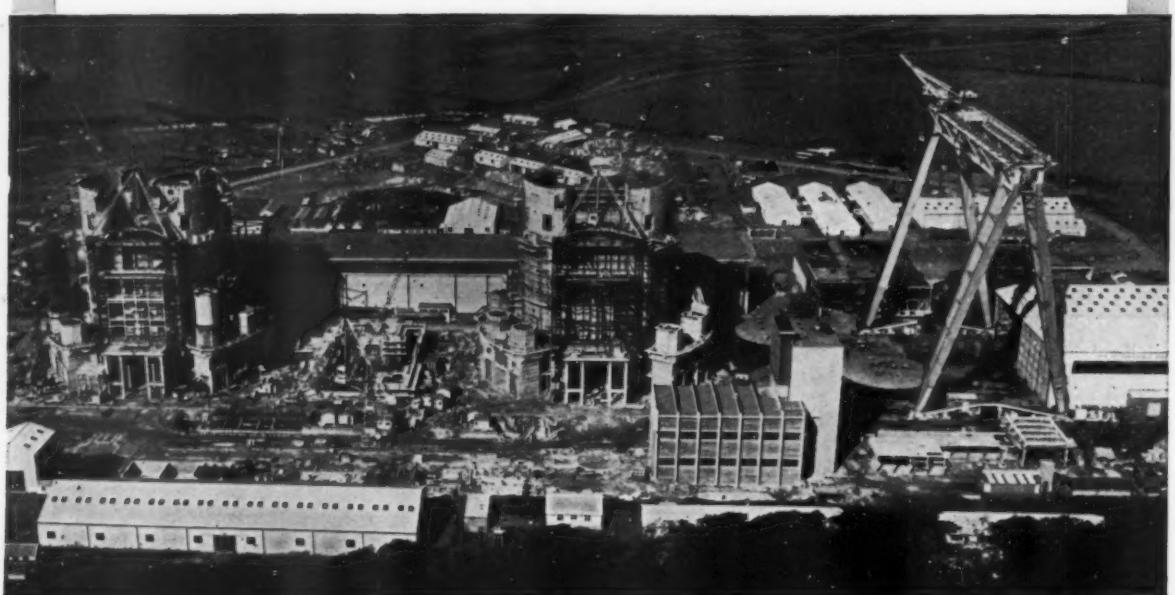
all the cable at Hunterston

is pg

19,500 yards of Pirelli-General 132 kV. single-core oil-filled cable are being installed between the transformers at the power station and switching station. The insulation of this cable is designed for 110 kV/cm. maximum working stress.

With the completion of this installation the whole of the cabling at Hunterston will have been carried out by Pirelli-General.

Hunterston is being constructed by the G.E.C.-Simon-Carves Atomic Energy Group. Consulting Engineers to South of Scotland Electricity Board, Kennedy and Donkin.



pg

PIRELLI-GENERAL CABLE WORKS LIMITED

SOUTHAMPTON AND EASTLEIGH

64'000 HP Pelton Turbine Göschenen

TRADITIONAL SWISS ENGINEERING SKILL AND QUALITY

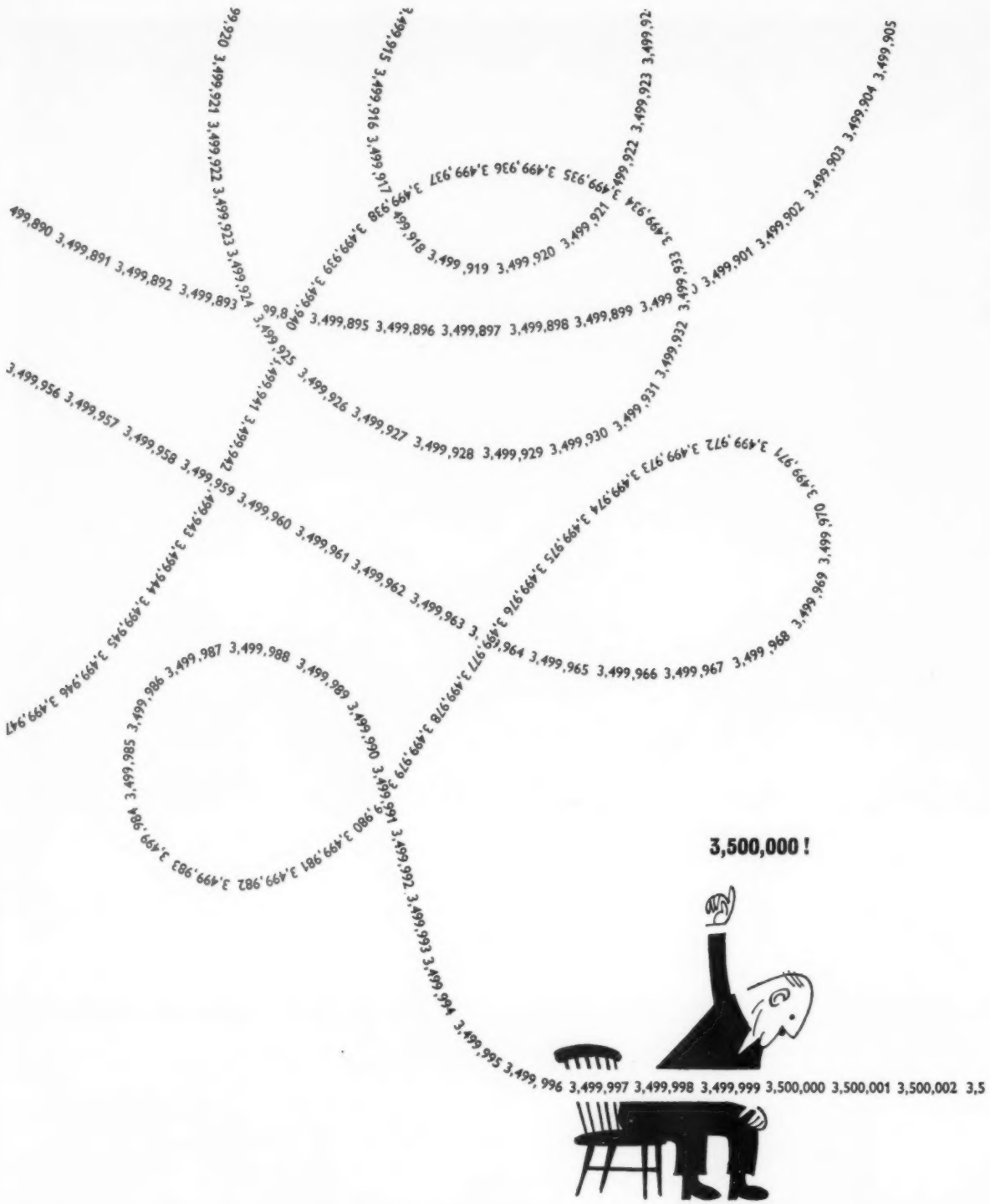
A century of experience in design and construction of waterpower-equipment and constant research in two hydraulic laboratories, one of them especially equipped for cavitation tests, assure the reliablity and efficiency for which Bell turbines are renowned

KRIENS Bell

Bell builds:
Water Turbines, Spherical straight flow valves, Butterfly valves, Penstocks and supply pipings, Pressure tunnel liners, Partially or fully automatic and remote controlled plants, Power house cranes, Towers for transmission lines, Water control equipment

Some projects with Bell Equipment:
Francis Turbines - Guyabo (El Salvador) head 56 m, 24'800 HP - Bärenburg (Switzerland) head 340 m, 85'000 HP (Supply together with Charmilles)
Pelton Turbines - Göschenen (Switzerland) head 698 m, 64'000 HP - Sedrun (Switzerland) head 588 m, 70'000 HP
Kaplan Turbines - Wildegg Brugg (Switzerland) head 15,3 m 34'000 HP - Petäjäskoski (Finnland) head 19 m, 67'600 HP

Bell Engineering Works Ltd.
Kriens/Lucerne (Switzerland)



3½ MILLION FEET DRILLED WITH VICTOR DRILL STEELS ON HYDRO-ELECTRIC CONTRACT IN 12 MONTHS

Victor Products (Wallsend) Limited, Wallsend-on-Tyne.

Victor

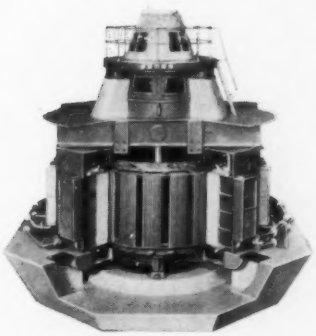
'Phone: Wallsend 628331/6.
'Grams: 'Victor' Wallsend

The Australian Prime Minister, the Rt. Hon. R. G. Menzies and Sir William Hudson, Commissioner for Snowy Mountains Hydro-Electric Authority, inaugurating the Tumut 1 Power-station.
(Photo: Snowy Mountains H. E. Authority)

640000 kVA

The Snowy Mountains Hydro-Electric Authority, Australia, has commissioned the first of two new power-stations, which together have a total output of 640,000 kVA. In the face of severe competition from leading electrical engineering firms from all over the world, ASEA was awarded the contract for all eight generators for these two power-stations.

Further generators having a total output of 127,000 kVA are also being manufactured at present by ASEA for Australia.

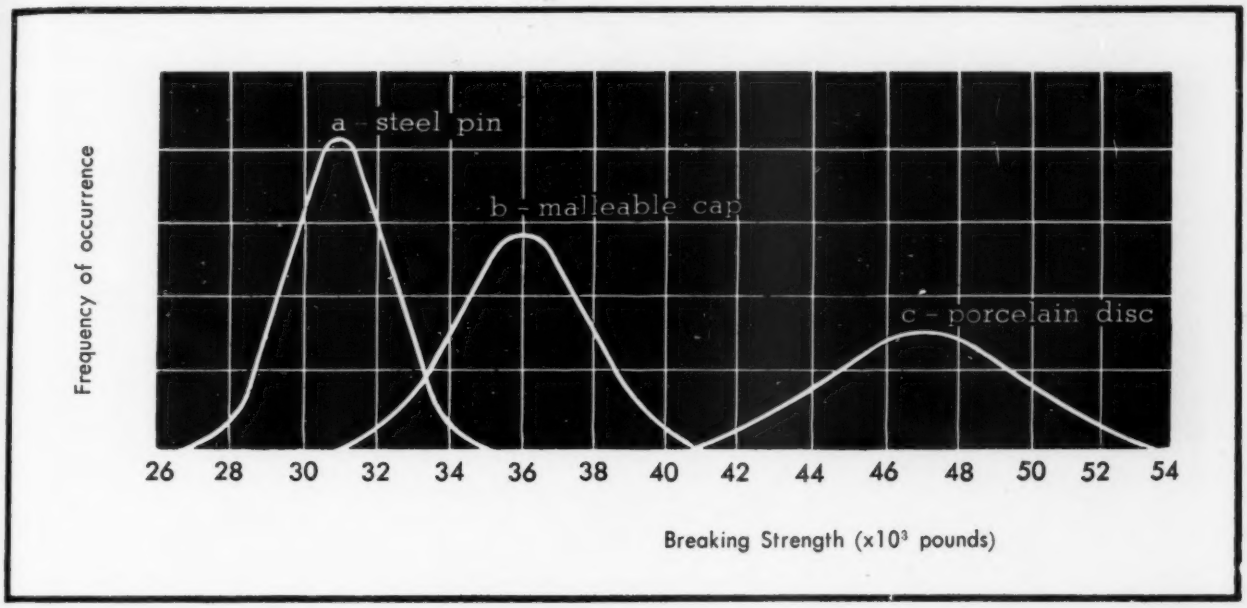


The largest power-station in Sweden, Stornorrfors, has an output of 450,000 kVA and supplies about 7 per cent of the total amount of electricity produced in the country. This power-station too is equipped with ASEA generators, and practically all electricity in Sweden is generated by ASEA machines.

VÄSTERÅS ASEA SWEDEN

Oerlikon supply
Alternators
Transformers
Switchgear
Traction equipment
Rectifiers
Electrolyzers
Magnets for nuclear research
Oerlikon Engineering Company
Zurich 50 Switzerland

SUPERIORITY IN PORCELAIN


a - steel pin
b - malleable cap
c - porcelain disc
Frequency of occurrence
26 28 30 32 34 36 38 40 42 44 46 48 50 52 54
Breaking Strength (x10³ pounds)

UNIFORMITY
STRENGTH
DURABILITY

UNIFORMITY? ..... no matter how good an insulator you choose you can't expect maximum efficiency and service unless they're uniformly balanced in strength.

Take, as an example, the standard NGK 10″ ball and socket disc insulator (rated 25,000 lbs. E & M Strength) and review the mechanical strength of each component by the histogram above. Uniform mechanical breakdown strength, always occurring at the pin, of the NGK Insulator unit is shown by Curve a; that of the cap by Curve b when a special pin is used; that of the porcelain by Curve c when using a special high strength cap and pin.

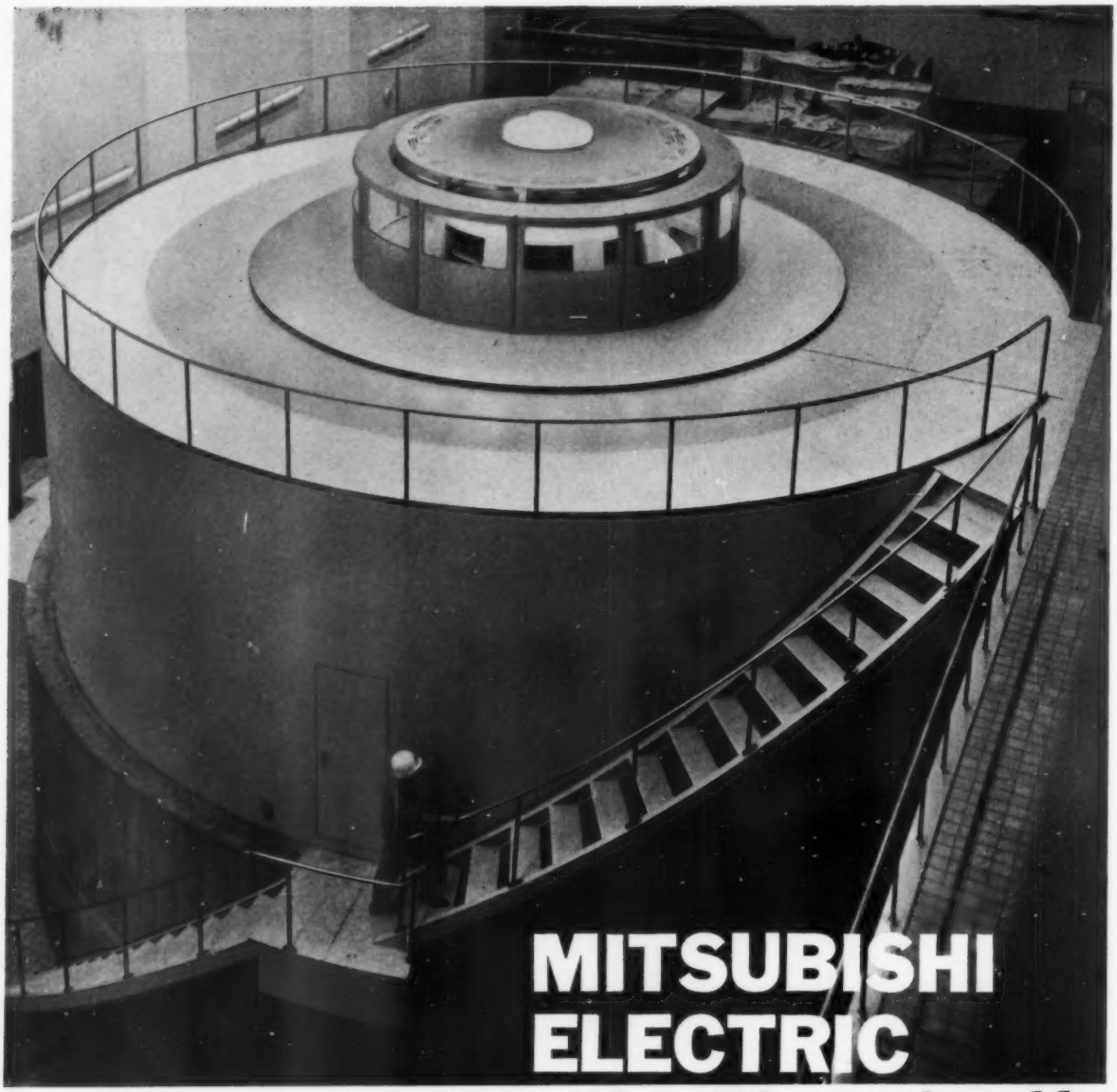
Insulator uniformity at a high level is your prime assurance to safe operation and maintenance economy.

You get so much more out of **NGK** *Insulators*

Nippon Gaishi Kaisha LTD.
MIZUHO NAGOYA JAPAN

Cable: INSULATOR Nagoya. TELEX: NGK-NG9928
Represented in all major territories

105,000 kVA Water-Wheel Generators

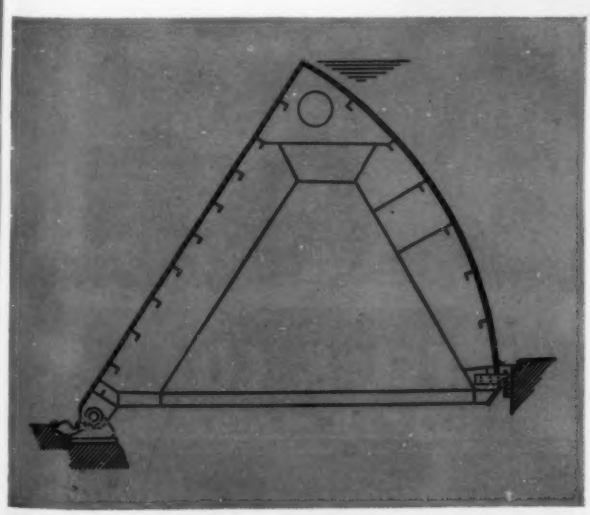


makes life comfortable

The comforts of life are the assured gifts of electric power...
Mitsubishi Electric engineers, workers... all perform their important tasks in making life comfortable..... they help in the manufacture of every type of electrical equipment from giant generators and transformers to small home appliances that make life easier. For matchless experience and a distinguished history of achievement, look to the THREE DIAMONDS of the Mitsubishi Brand... the symbol of QUALITY and INTEGRITY.

MITSUBISHI ELECTRIC MANUFACTURING COMPANY
Head Office: Tokyo Building, Marunouchi, Tokyo Cable Address: MELCO TOKYO

M·A·N

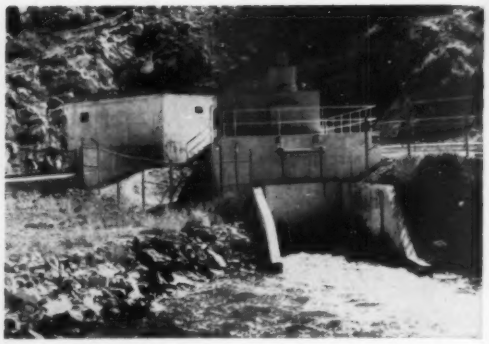


HYDRAULIC STRUCTURES

Sector weir of 50 m clear width and 4.55 m water head in the River Elbe at Geesthacht near Hamburg. Illustration shows the gate in course of erection. Sector weirs are hydraulically operated submersible gates moved by regulation of the water enclosed in the sector chamber. As opposed to drum gates, they are particularly appropriate for weir plants in rivers where comparatively slight variation in the water level occurs.

MASCHINENFABRIK AUGSBURG-NÜRNBERG AG · GUSTAVSBURG WORKS
GUSTAVSBURG/HESSEN (GERMANY) · REPRESENTATIVES IN ALL COUNTRIES

1001/58



▲ Interior of the Wanship Power Plant, looking across the Leffel turbine toward the control cabinets.

◀ Wanship Power Plant, located in Wanship Dam on the Weber River approximately one mile upstream from Weber, Utah.

3 Leffel Turbines Provide Power for the Bureau of Reclamation's Weber Basin Project

Gateway and Wanship Power Plants, units in the United States Bureau of Reclamation's Weber Basin Project, were constructed to provide power for project use . . . primarily for pumping irrigation and drainage water.

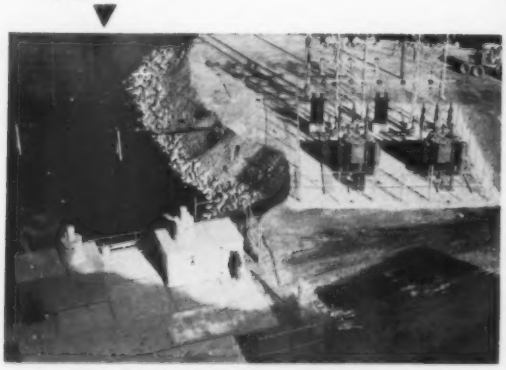
Three Leffel vertical shaft, spiral case turbines, two at Gateway and one at Wanship, drive the generators which supply this vital power. Each of the Gateway turbines is rated at 2900 H.P. at 514 R.P.M. under 140 foot net head. The Wanship turbine is rated at 2000 H.P. at 450 R.P.M. under a 116 foot net head.

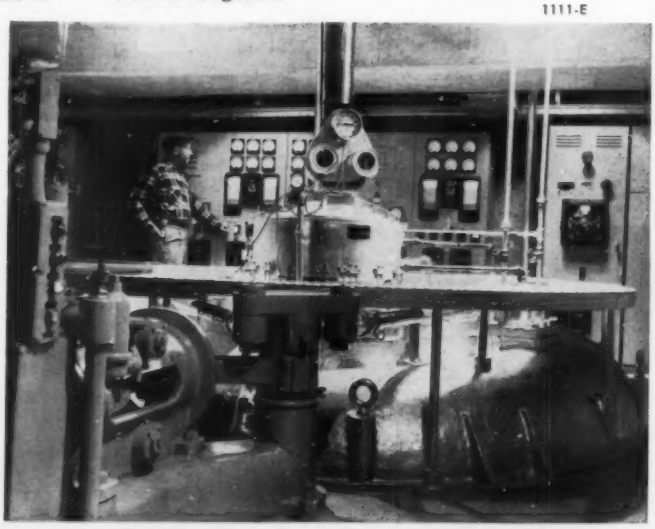
Successful installations such as these in all parts of the world testify to Leffel's ability to design turbines for high efficiency and build them for long life and reliable operation. And every Leffel turbine is backed by nearly a century of experience in water power development. Be sure to take advantage of this experience on your next project. It's available without obligation.

1111-E

Interior of the Gateway Power Plant, showing one of the two Leffel turbines. ▶

Gateway Power Plant, located on the Gateway Canal approximately 15 miles west of Morgan, Utah. ▼





FOUNDED IN 1862

THE JAMES LEFFEL & CO.

DEPARTMENT W • SPRINGFIELD, OHIO, U. S. A.

MORE EFFICIENT HYDRAULIC POWER FOR 99 YEARS

+GF+ Quality Steel Castings

have been chosen for the most famous pump storage schemes:

Ffestiniog	Pump casings, impellers, Francis runners
Lünersee	Pump casings, impellers, wheels for hydraulic torque convertors, Pelton runners
Gougra Motec	Pump casing, Pelton runners, rotary valves

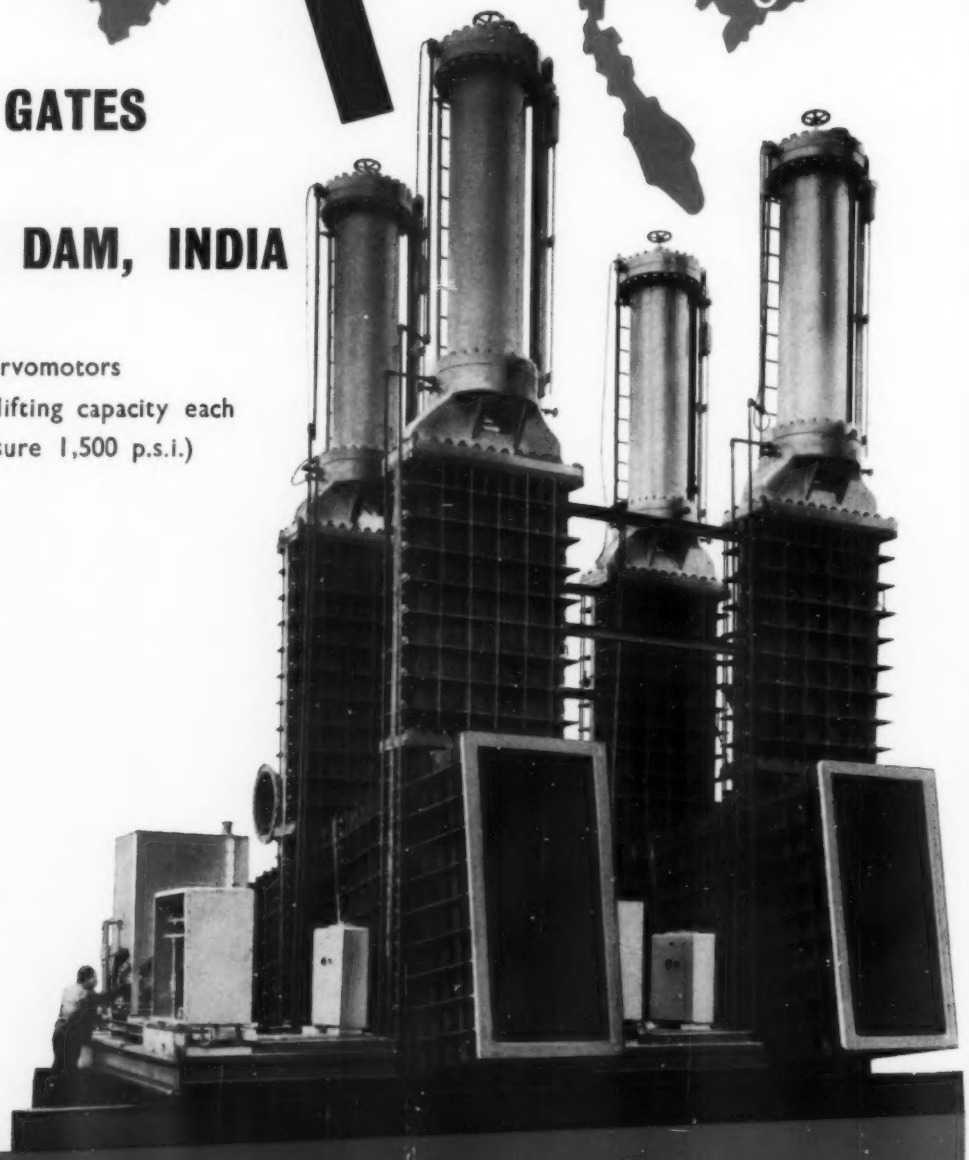
George Fischer Limited
Schaffhausen, Switzerland

Telephone: (053) 5 60 31 / 5 70 31
Telegrams: Geofischer

Sg 716/4

SLUICE GATES for RIHAND DAM, INDIA

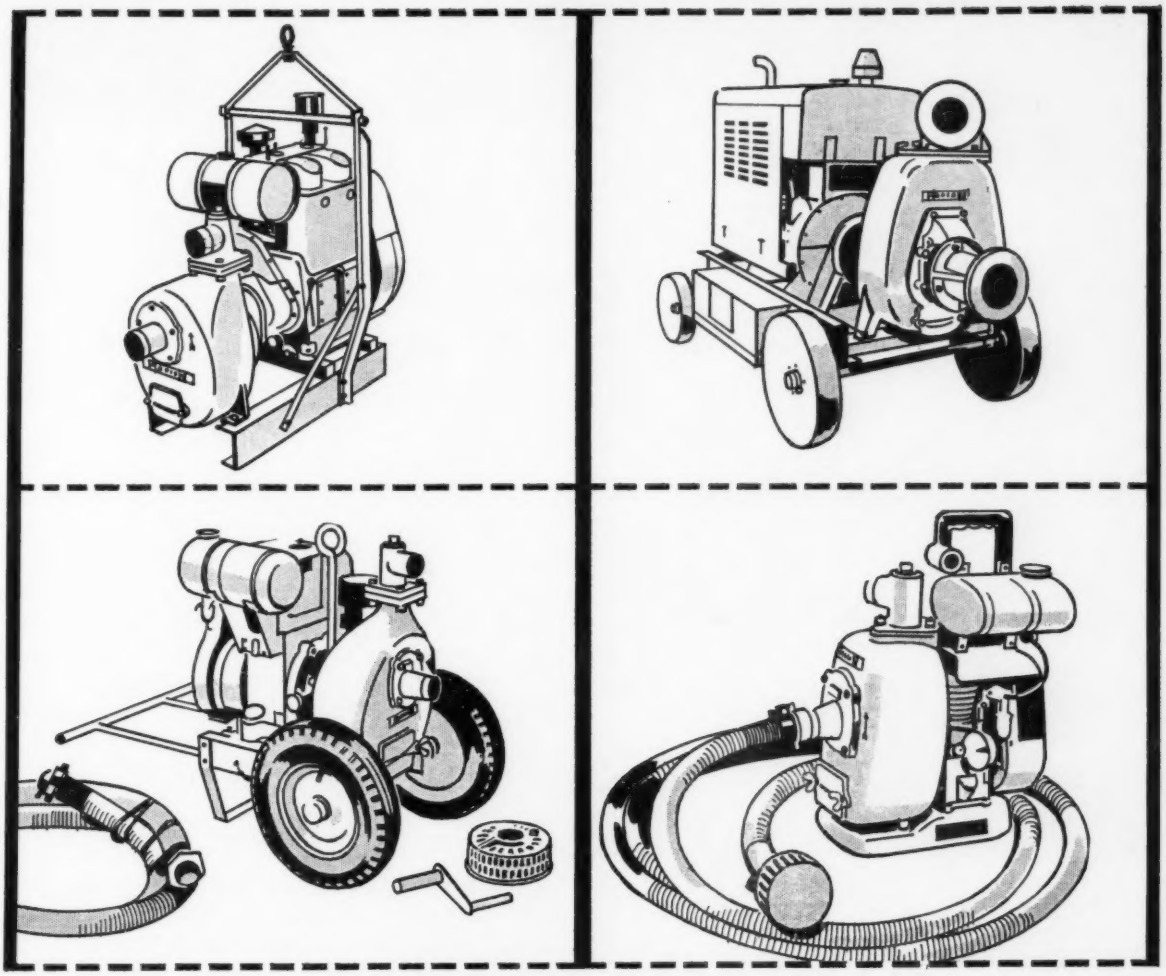
Oilhydraulic Servomotors
of 500.000 lbs lifting capacity each
(Working pressure 1,500 p.s.i.)



WAAGNER-BIRÓ A.G.

WIEN GRAZ

Head Office: Vienna V., Margaretenstrasse 70 / Austria



RAPIER

Self Priming Water Pumps

No other Pumps give you all these advantages

- Patent Fully Automatic Self Priming – no valves or adjusters – giving quicker prime and larger air capacity than any other pumps of their size.
- Can pump extremely dirty water, containing up to 25% solid matter in suspension.
- High output at all lifts.
- Utterly reliable in day to day working – *and in emergencies.*
- Petrol, diesel, electric or independent drive.
- Sizes up to 80,000 gallons per hour.

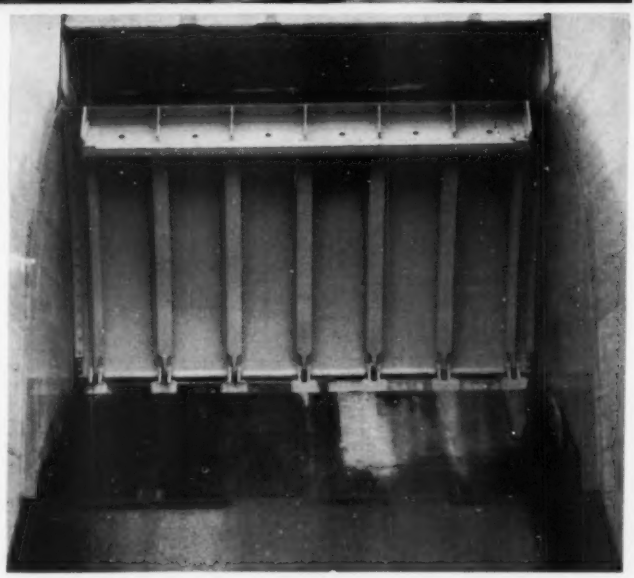
RANSOMES & RAPIER LIMITED ENGLAND

A Newton Chambers Company

IPSWICH – Waterside Works *Telephone:* Ipswich 56383 *Telex:* Rapier 1876 Ipswich *Telegrams and Cables:* Sluice, Ipswich, Telex
LONDON – 31 Victoria St. S.W.1 *Telephone:* London Abbey 6383 *Inland Telegrams:* Sluice, Sowest, London *Cables:* Sluice, London

GATES

for Spillway Crests



In numerous instances, in many countries, control on the spillway crests of hydro-electric dams is effected by Glenfield Gates.

Types available include direct-lift, drum, radial and tilting. Illustrated are two 90 ft. span by 16 ft. deep Drum Gates, and a 20 ft. span by 10 ft. deep Tilting Gate; all of which are arranged for automatic working in accordance with changes in the upstream water level.

Glenfield

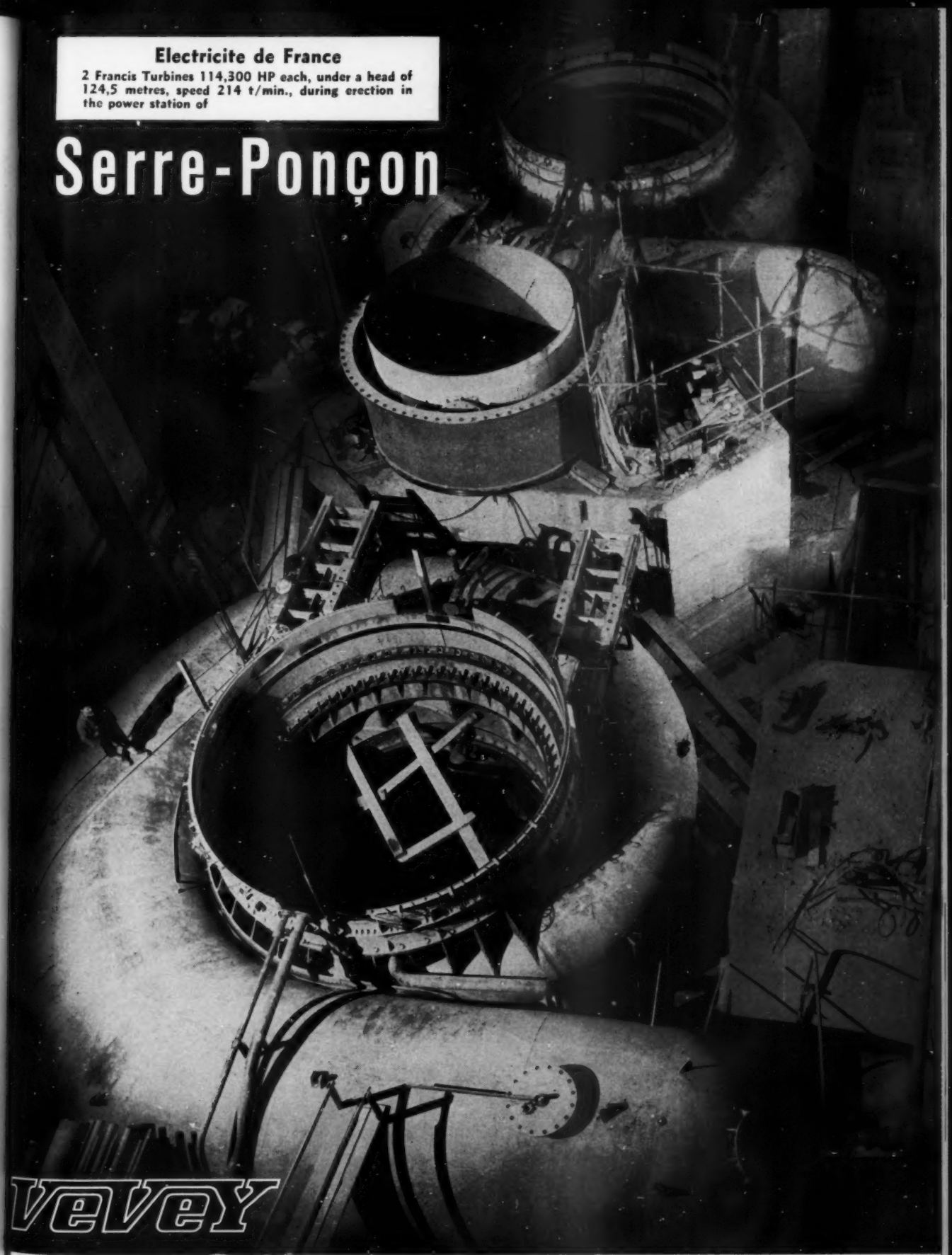
GLENFIELD & KENNEDY LIMITED KILMARNOCK

Head Office & Works : KILMARNOCK · SCOTLAND

Electricite de France

2 Francis Turbines 114,300 HP each, under a head of 124,5 metres, speed 214 t/min., during erection in the power station of

Serre-Ponçon

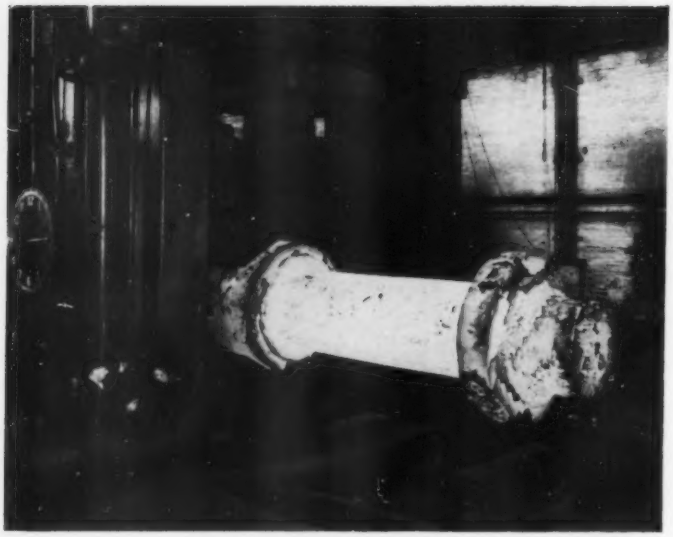


VEVEY

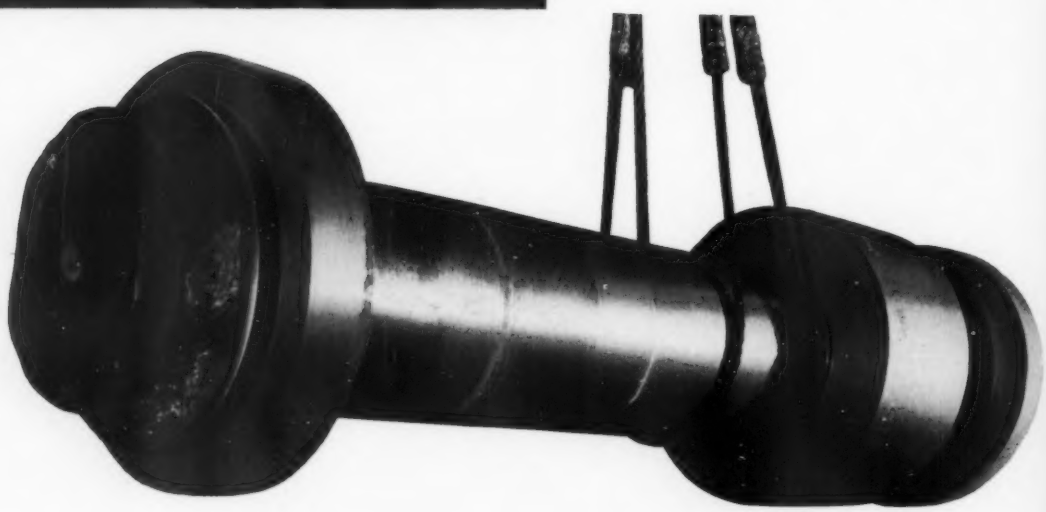
Vevey Engineering Works Ltd.

Vevey (Switzerland)

in collaboration with our French licensee:
Cie des Ateliers et Forges de la Loire, St-Chamond (Loire)



For many years ESC has been the leading supplier of steel forgings to many vital industries. Forgings in weights up to 175 tons are manufactured in our high quality carbon and alloy steels—single piece engineering units produced from ingots weighing up to 300 tons—and



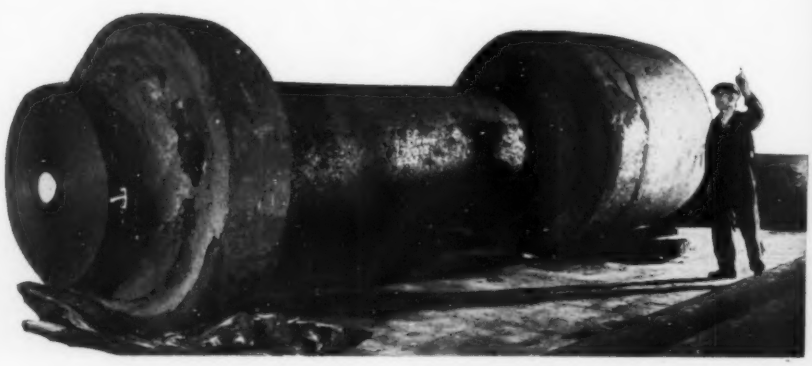
other forgings from ingots 30 cwt. and upwards—for all branches of engineering.

ENGLISH STEEL FORGE AND ENGINEERING CORPORATION LTD.

River Don Works, Sheffield

A wholly owned subsidiary of English Steel Corporation Ltd.

Illustrations show a forging operation under a 7,000 ton electro-hydraulic press, rough machined and black forged steel Turbine shafts, 22′ 11″ long, 3′ 8″ diameter with 6′ 2″ and 6′ 4″ diameter couplings— Weight as forged 111½ tons, rough machined 70 tons—for a modern hydro-electric power project.

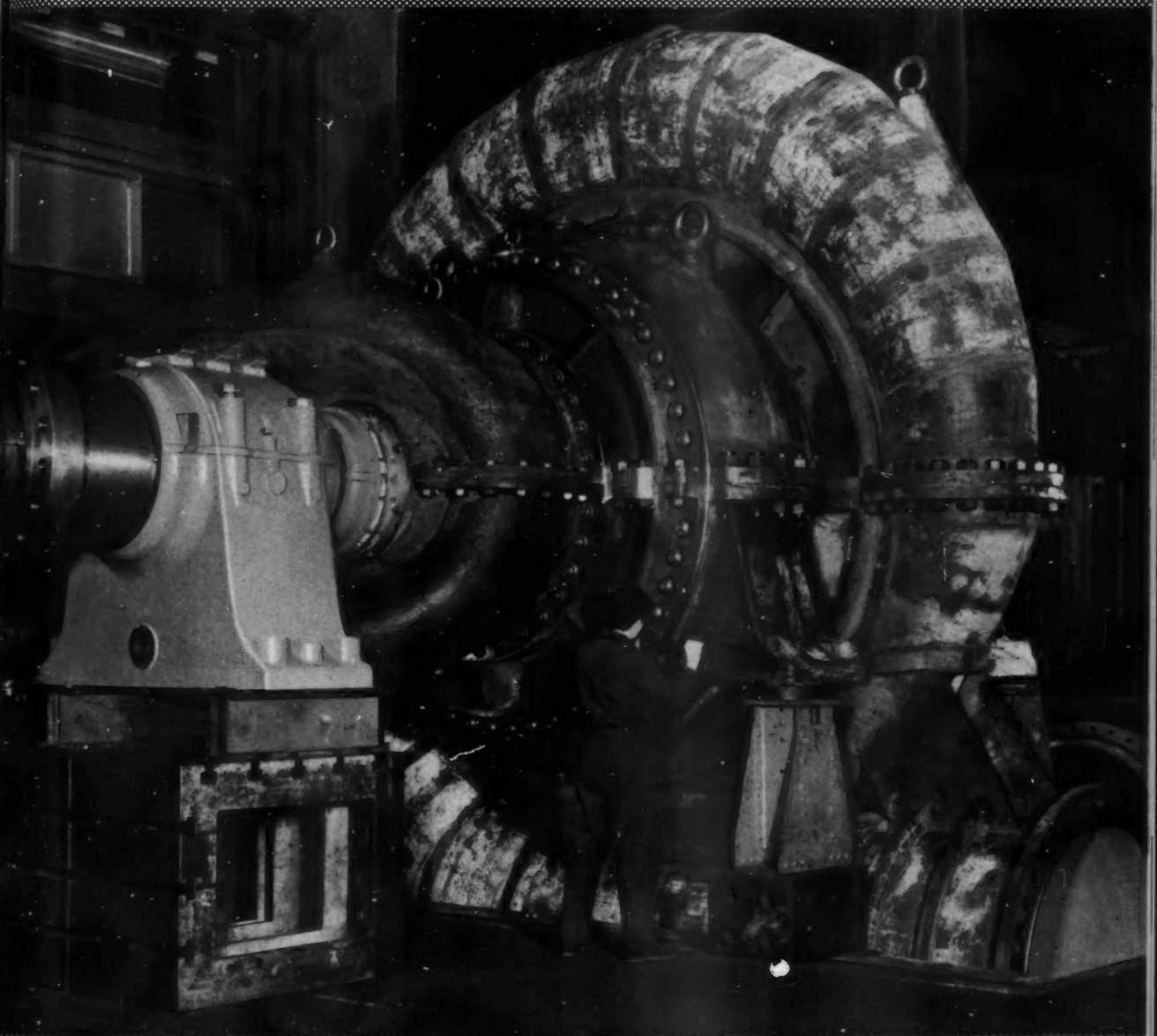


SOCIETA' GENERALE ELETTRICA DELLA SICILIA

GUADALAMI SCHEME

WE ARE SUPPLYING FOR THIS PROJECT:

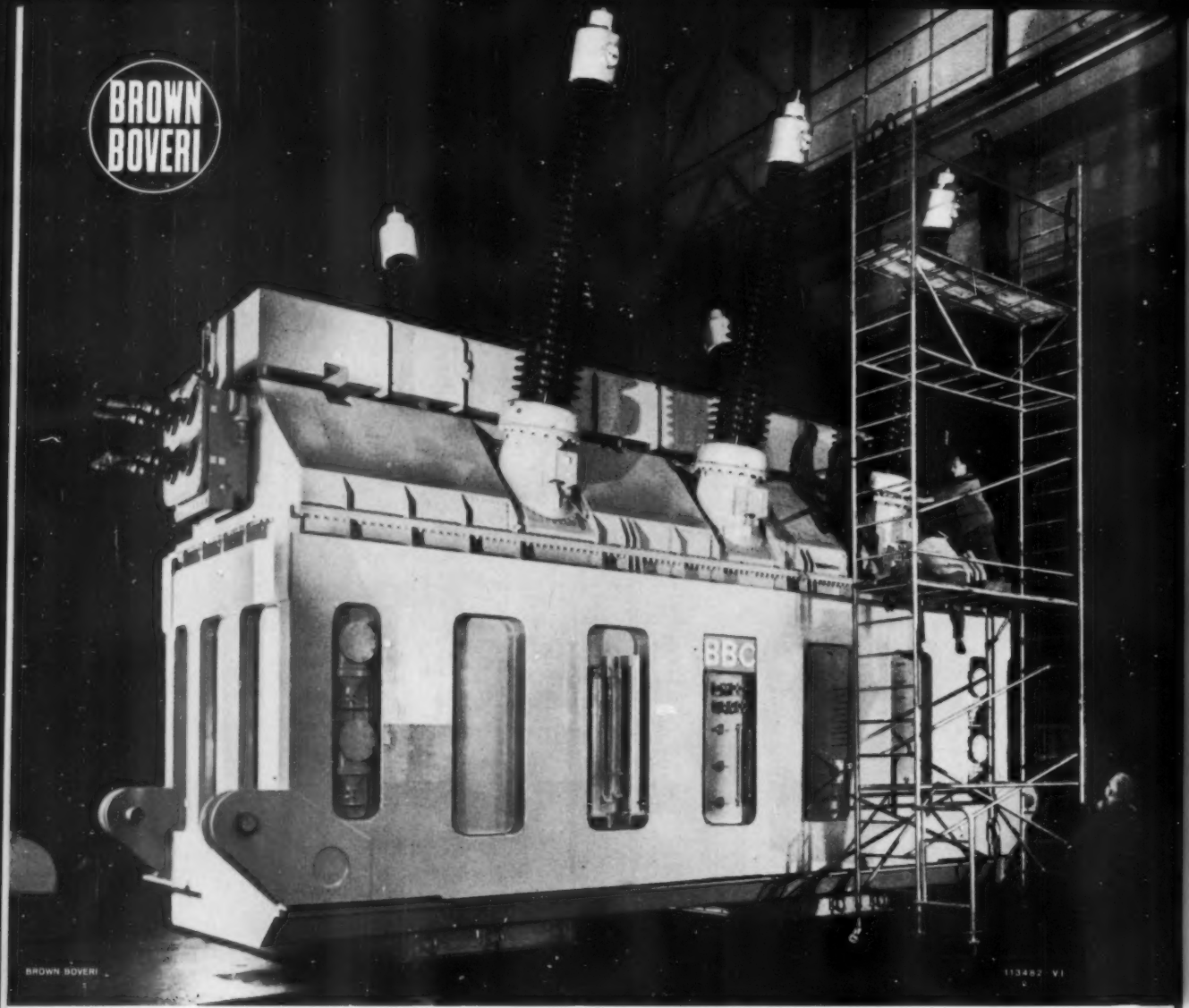
- TWO 40,000 h.p. STORAGE PUMPS
- TWO 43,000 h.p. FRANCIS TURBINES
- ONE 31,000 h.p. FRANCIS TURBINE



RIVA

COSTRUZIONI MECCANICHE RIVA

VIA STENDHAL 34 MILANO ITALY



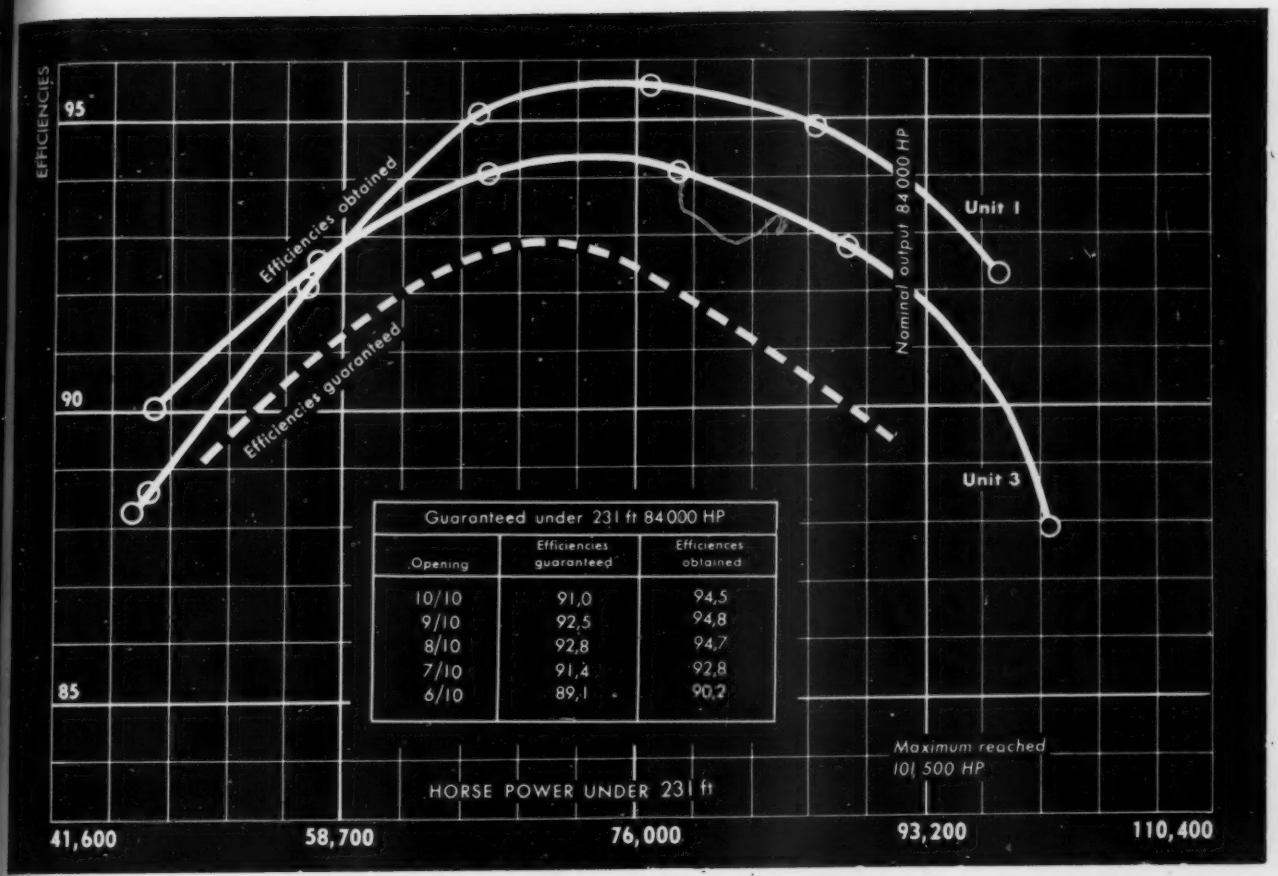
542000 kVA

The largest output ever transformed in a single unit

This immense three-phase transformer with the highest rating for which a single transformer was ever built, 542000 kVA at 330/240 kV, stands over 25 feet high when ready for service, weighs over 250 tons with its cooling system and was built by Brown Boveri, Mannheim, for a large power undertaking in Western Germany.

BROWN, BOVERI & CO., LTD.
BADEN · SWITZERLAND

Represented in England by British Brown-Boveri Ltd., 75 Victoria Street, London S.W.1



PICOTE NEYRPIC TURBINES EXCEED EXPECTATIONS

PICOTE
P o r t u g a l

The sound qualities of Neyrpic turbines were again confirmed at Picote when the efficiencies of units 1 and 3 exceeded the guaranteed values

2560

NEYRPIC
Avenue de Beauvert · GRENOBLE

HITACHI

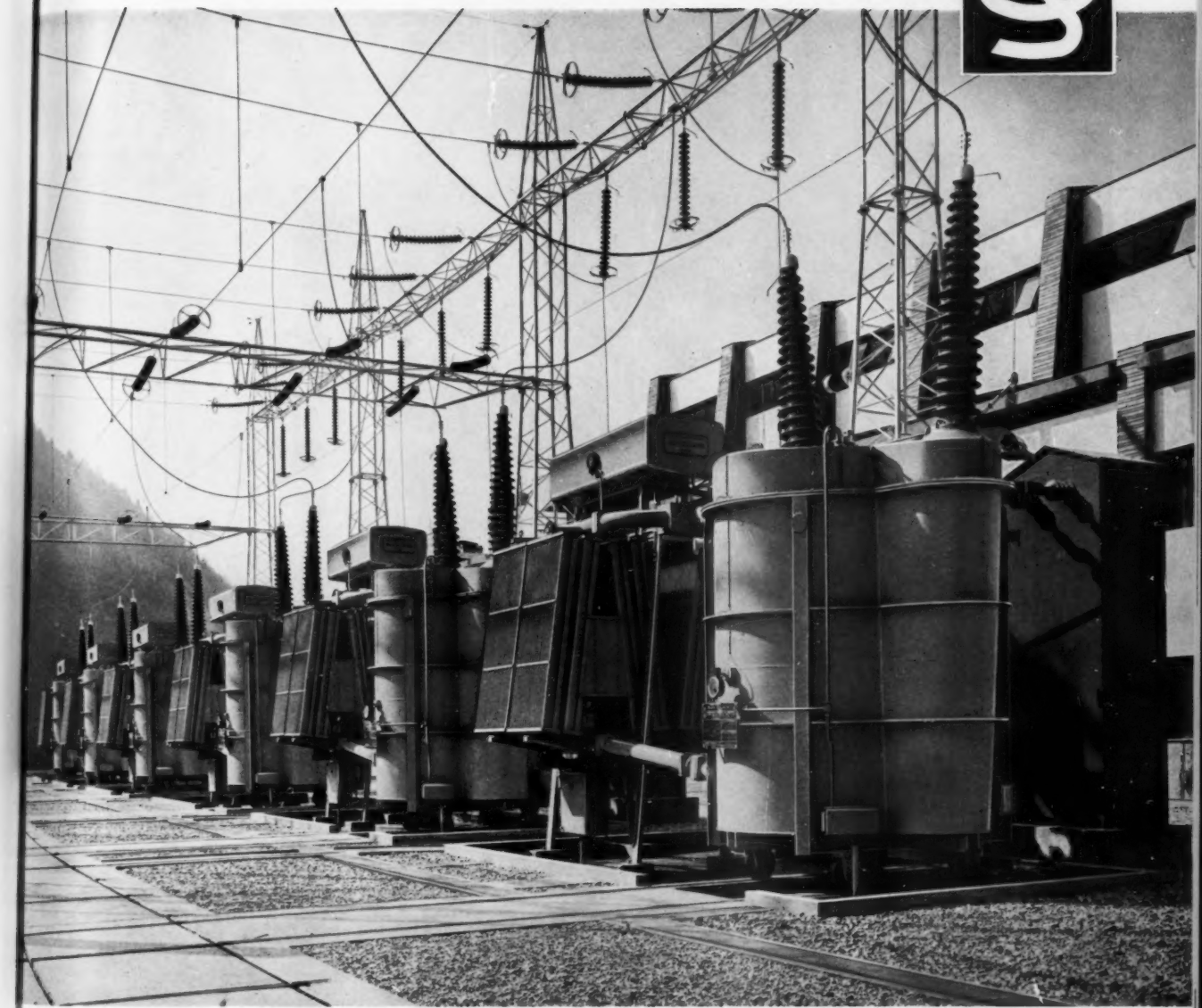
Another Big Hydraulic Turbine and Generator by Hitachi

Hitachi has recently completed two 137,500 kW/125,000 kVA hydraulic turbines and generators for the Miboro Power Station in Central Japan. The turbine is of the vertical-shaft Francis type, and specified for a speed of 225 r.p.m., a maximum effective head of 200m and 76.6 cu.m/sec. water flow, making it one of the largest units of its kind in the world. Its runner has a maximum diameter of 3.7m and the main shaft a diameter of 95cm. The spiral casing, which was constructed in 13 sections to facilitate transportation to the site, has an inlet diameter of 3.35m and an outer diameter of 11.2m.

The generator presents a high-torsoed appearance, having been so designed in consideration of the comparatively high speed. Since the generator was designed for a rated voltage of 16,500 volts and, in this respect, represents the first such attempt in Japan, particular care was taken in the corona-shielding and impulse resistance of the stator winding. The generator is rated at 60 cycles, 225 r.p.m. and 0.9 power factor, but is also capable of operating at 50 cycles, 187.5 r.p.m. and 1.0 power factor.

Hitachi, Ltd.
Tokyo Japan

Cable Address: "HITACHY" TOKYO



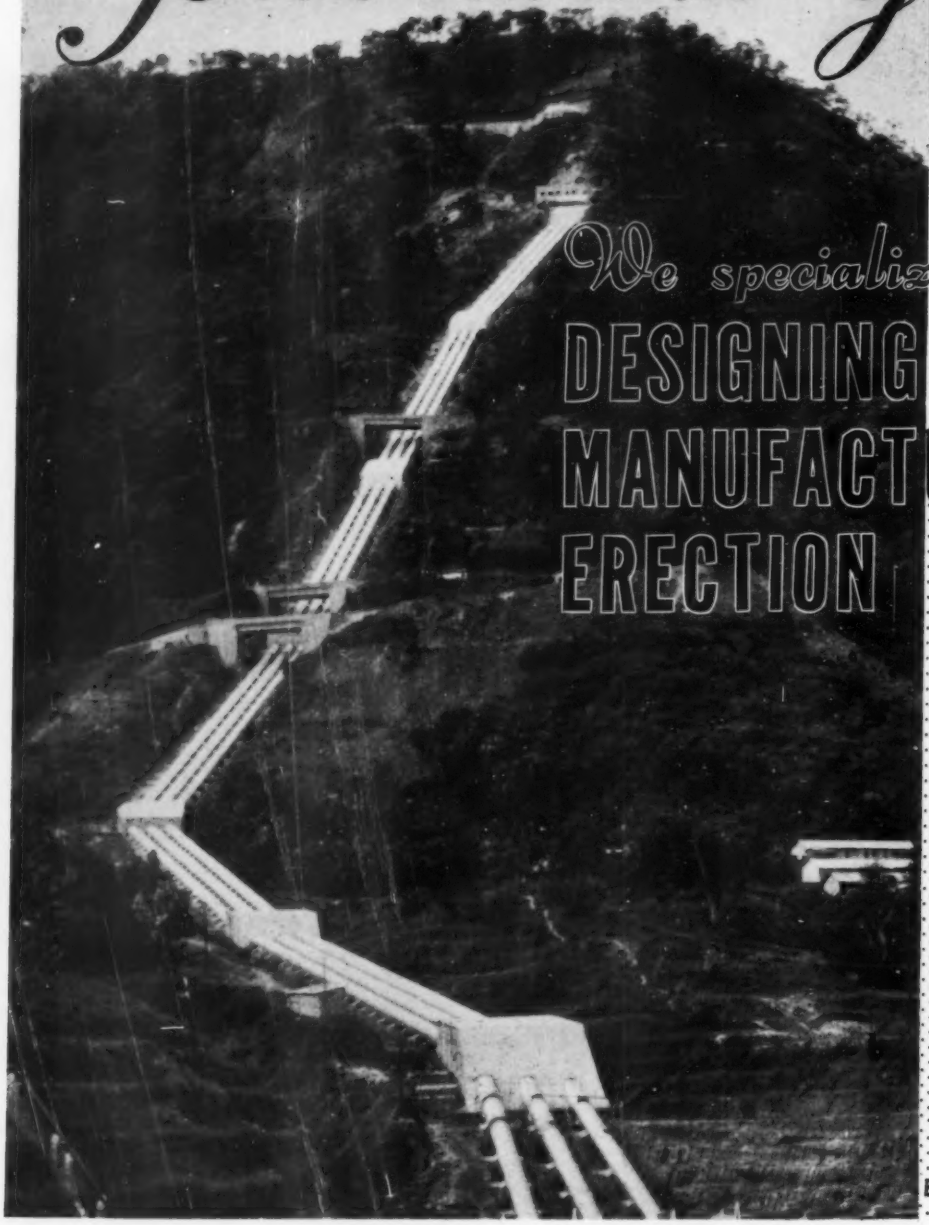
Six single-phase transformers, cooled by separately mounted radiators, forming two 75 MVA three-phase banks, ratio 11 ± 5% / 260 kV. These transformers have been supplied to C.E.B. (Consorzio Elettrico del Buthier), Turin, Italy, for the Valpelline power station; and they have the highest voltage in the Aosta Valley power system.

società nazionale delle officine di

savigliano

Corso Mortara 4 - TORINO (ITALIA)

Penstock and Gate



We specialize in . . .

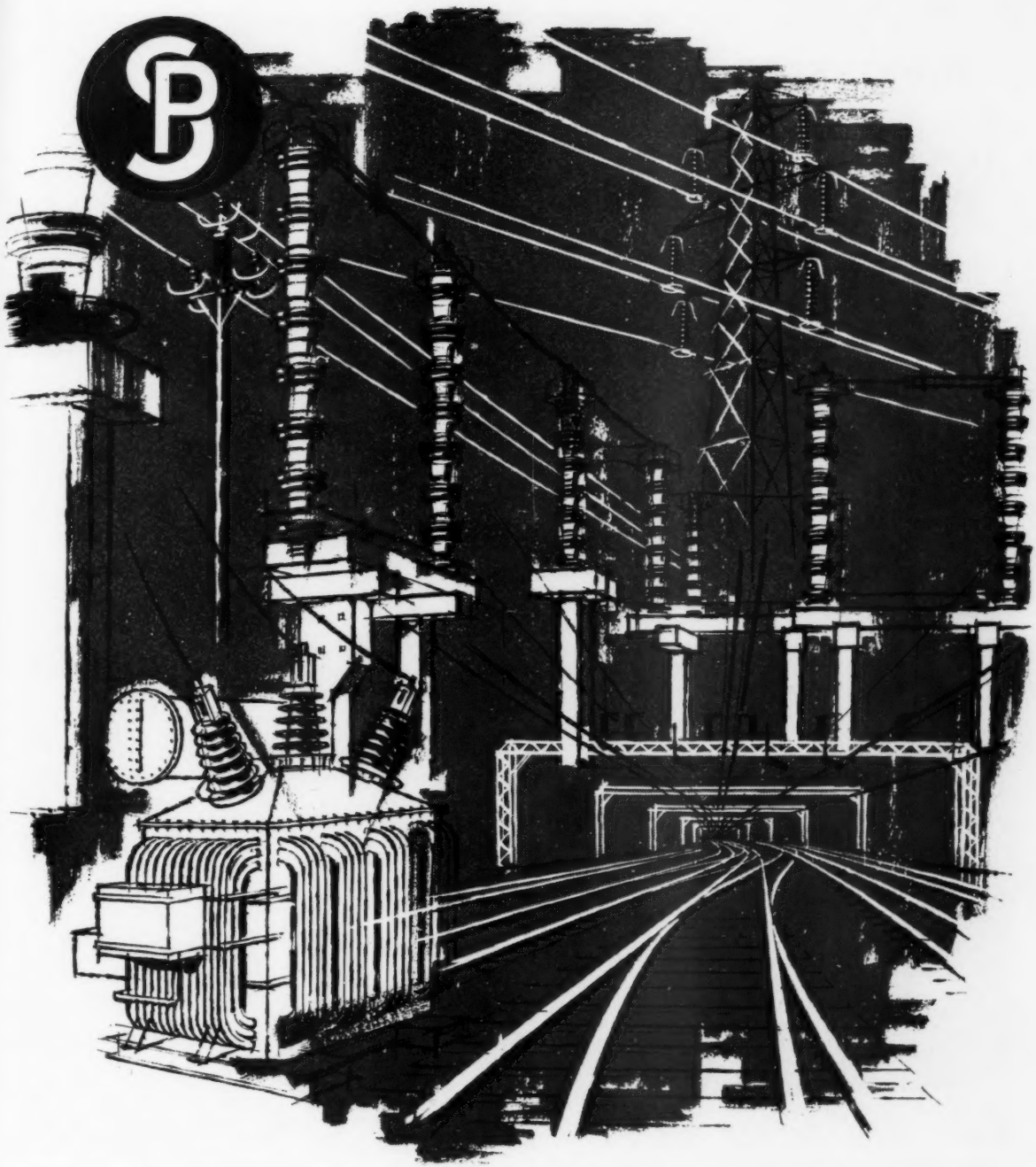
DESIGNING
MANUFACTURING
ERECTION

Established: 1904

SAKAI IRON WORKS CO., LTD.

HEAD OFFICE: NISHI, 6-CHOME, TSUMORI-CHO, NISHINARI-KU, OSAKA, JAPAN CABLE ADDRESS: "SAKATETSU OSAKA"

TOKYO OFFICE: NIHONBASHI-GOFUKUBASHI, CHUO-KU, TOKYO, JAPAN CABLE ADDRESS: "SAKATETSU TOKYO"



HIGH VOLTAGE INSULATORS

The outstanding quality of S & PP insulators is the result of over 30 years' experience in the manufacture of high voltage porcelain insulators.

- **Overhead line insulators**
- **Switchgear post insulators**
- **Transformer bushings**
- **Insulators for railway electrification**
- **Custom-made porcelains**

STEATITE AND PORCELAIN PRODUCTS LIMITED

STOURPORT ON SEVERN, WORCS. TEL: STOURPORT 2271 GRAMS: STEATAIN, STOURPORT S.P.103

LOCH GIORRA DAM

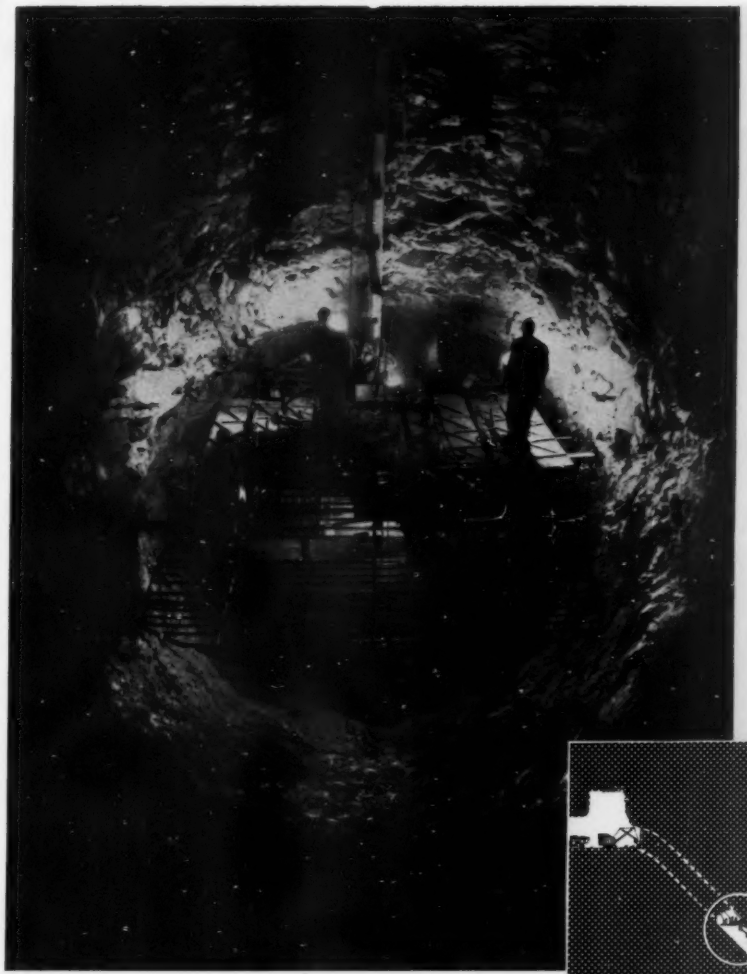
The new Giorra Dam shown below was built by Edmund Nuttall, Sons & Co. (London) Ltd., for the North of Scotland Hydro-Electric Board. The dam, which is 1,450 feet long and 100 feet high, stands at the eastern end of Loch Giorra and forms an important part of the Breadalbane Power Scheme.

Authority: North of Scotland Hydro-Electric Board
Consulting Engineers: James Williamson & Partners

EDMUND NUTTALL

CIVIL ENGINEERING CONTRACTORS

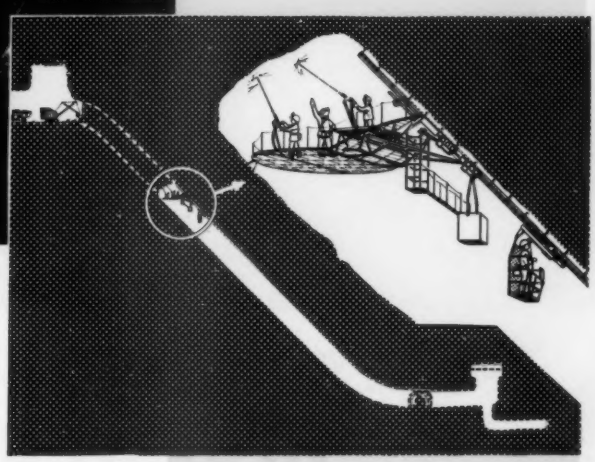
EDMUND NUTTALL SONS & CO. (LONDON) LTD. 22 GROSVENOR GARDENS, LONDON S.W.1 PHONE: SLOANE 0036



Swedish State Power Board

breaks

WORLD RECORD



For driving the Feed Tube the Swedish State Power Board decided to employ the Alimak Method and the Alimak Drilling Platform. The tube could then be driven full size in one step.

The crew of six, using a specially designed Alimak Verken Raise-Climber, has now completed the 800 x 22-foot tube with an inclination of 47°. The job was done in seven months — a world record for this type of construction. The estimated time using conventional methods was 24 months.

For further information apply to

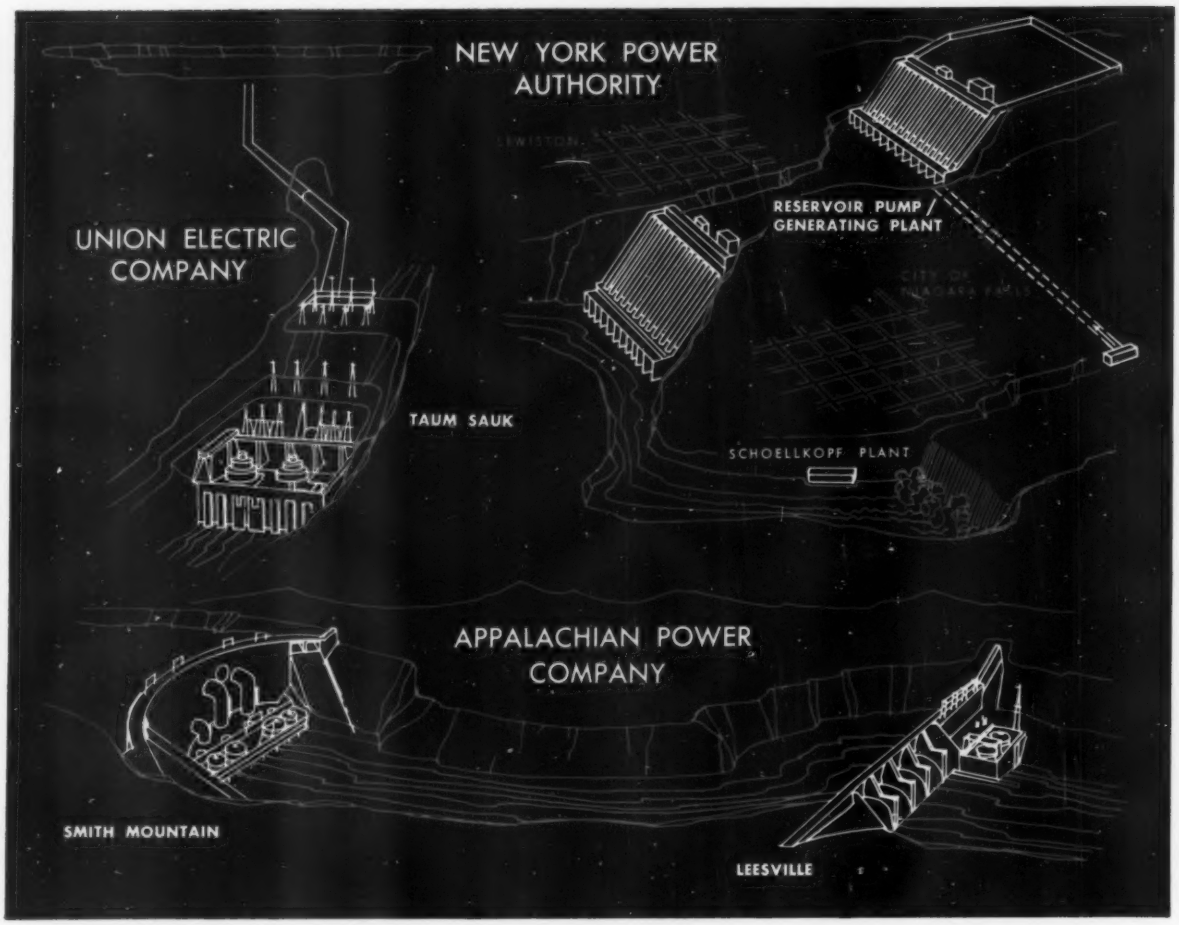
ALIMAK

VERKEN AB

SKELLEFTEA **SWEDEN**

Cables: Alimak Telephone: 14230 Telex: 6883

ALLIS-CHALMERS



Just what you'd expect from the pumped-storage pioneer:

first in all three

Pumped-storage power projects now under construction in this country all rely on Allis-Chalmers reversible pump-turbines. In fact, A-C is the only builder of complete reversible pump-turbine equipment!

First in boosting existing hydro at Niagara Reservoir pump/generating plant! This pumped-storage project will capitalize on the hydro-electric power potential of Niagara River without adversely affecting the scenic beauty of the Falls. Largest project of its kind, this installation will include 12 reversible pump-turbines with motor-generators . . . all designed and fabricated by Allis-Chalmers. As a turbine, each unit is rated 28,000 hp under 75-ft net head; as a pump, 3,400 cfs at 85-ft total head.

First in pure regeneration — at Taum Sauk! . . . also to have the largest-capacity hydro units ever built. Allis-Chalmers will supply two 175,000 kw reversible pump-turbines, each with a capability exceeding 300,000 hp under 800-ft head. (Pure regeneration installations need only a water supply to replace evaporative losses, so a creek is ample. Even a hill is unnecessary: the pool can be underground, in an abandoned mine shaft, for example.)

First in run-of-river — at Smith Mountain! This new project involves reservoirs at two successive levels, the lower dam forming a tailrace pool at the upper dam for two A-C reversible pump-turbines, each rated 87,000 hp at 180-ft head. Conventional hydro-generating units will also be installed — two higher-head units at the upper dam and two lower-head units at the lower dam.

For complete information on pumped-storage, hydro-generating equipment or other components for water control, contact your nearby A-C office. Or write to **Allis-Chalmers,** *Hydraulic Division, York, Pa.* A-1385

"It's agin' nature," growled Brock the Badger. "The years it took me and my family to dig out our home. Now these Mitchell people build this here all in a minute."
"*Not in a minute,*" *squeaked the squirrel.* "*Not even Mitchells are as good as that!*"
"And it's here to stay. I know a good job when I see it."
"*You're quite right. People who require the services of an experienced firm of building and civil engineering contractors ought to get in touch with Mitchell Construction.*"

MITCHELL CONSTRUCTION

BUILDING & CIVIL ENGINEERING CONTRACTORS
THE MITCHELL CONSTRUCTION COMPANY LTD
WHARF WORKS · PETERBOROUGH

P.4017

Gravesend's biggest—for Leicester

The largest oil-filled cable ever to be made at AEI's Gravesend Works is this 132 kV 3-core giant, laid under the busy streets of Leicester. 8,000 yards of this cable was installed by the AEI Construction (Cables and Lines) Division for the East Midlands Electricity Board, to reinforce the supply to the northern area of the city.

Some vital statistics: 0.60 sq. in. compacted circular copper conductors; aluminium oil ducts; lead sheathed with tin bronze reinforcement and protected with anti-corrosion serving; overall diameter 4.85 in. Supplied on 11 ft. diameter drums weighing 12 tons each.

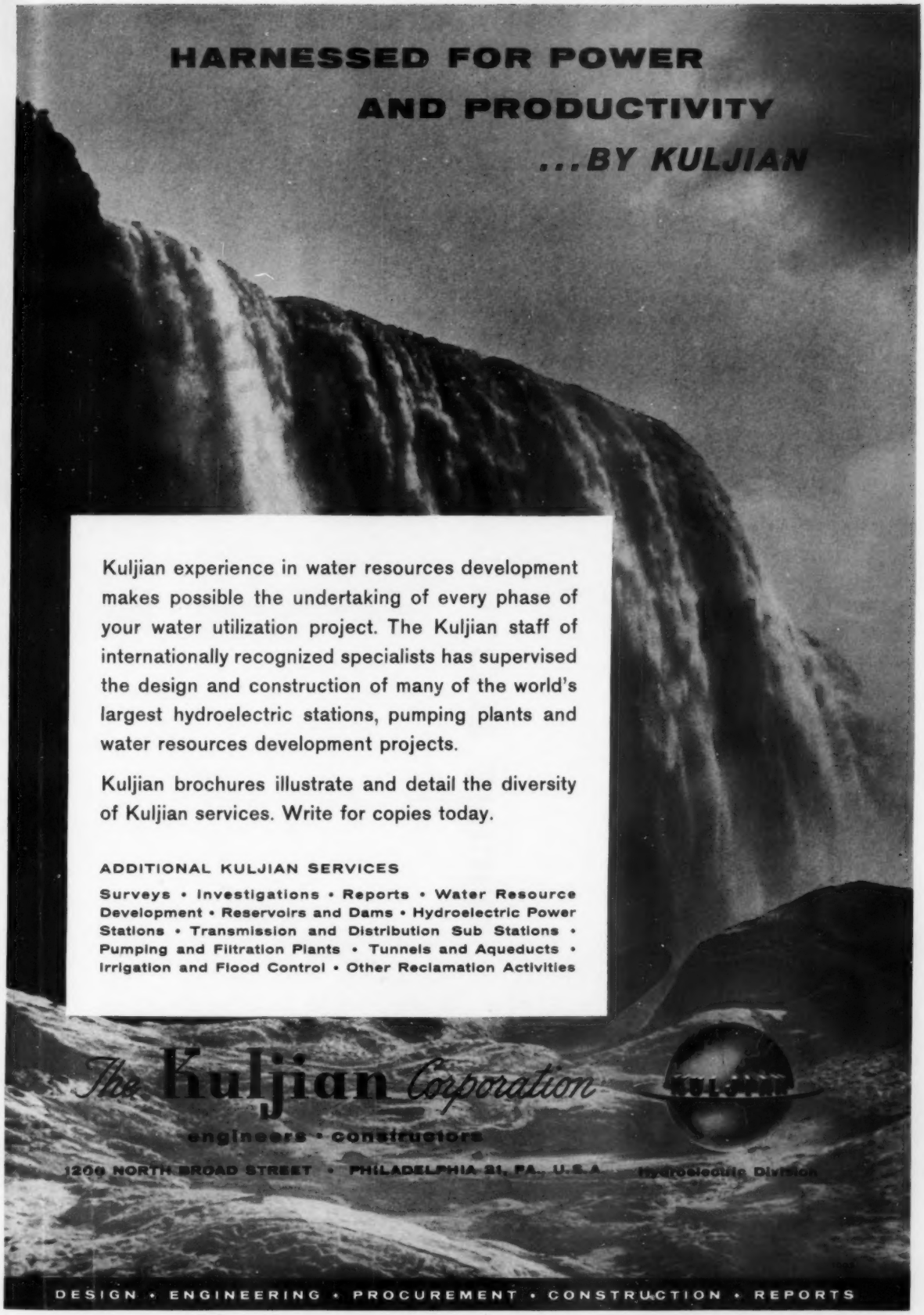
AEI

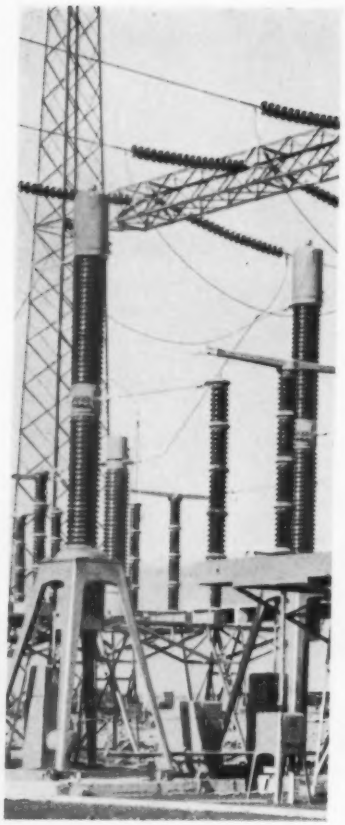
CABLE DIVISION

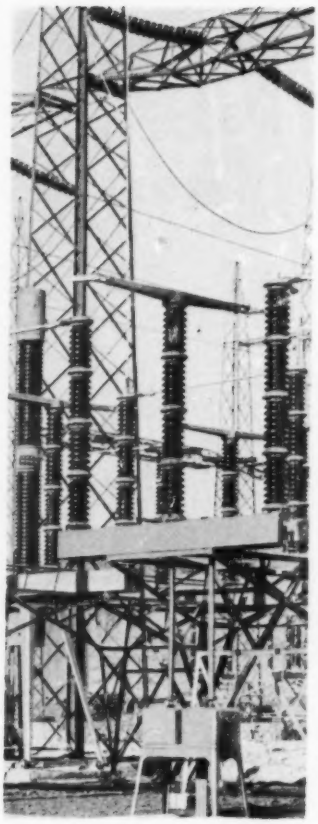
Associated Electrical Industries Limited

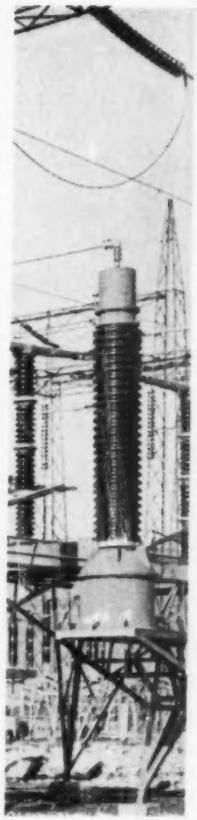
Cable Sales Department

51-53 Hatton Garden, London E.C.1. Phone: CHAncery 6822


HARNESSED FOR POWER
AND PRODUCTIVITY
...BY KULJIAN
Kuljian experience in water resources development makes possible the undertaking of every phase of your water utilization project. The Kuljian staff of internationally recognized specialists has supervised the design and construction of many of the world's largest hydroelectric stations, pumping plants and water resources development projects.
Kuljian brochures illustrate and detail the diversity of Kuljian services. Write for copies today.
ADDITIONAL KULJIAN SERVICES
Surveys • Investigations • Reports • Water Resource Development • Reservoirs and Dams • Hydroelectric Power Stations • Transmission and Distribution Sub Stations • Pumping and Filtration Plants • Tunnels and Aqueducts • Irrigation and Flood Control • Other Reclamation Activities
The Kuljian Corporation
engineers • constructors
1200 NORTH BROAD STREET • PHILADELPHIA 21, PA., U.S.A.
Hydroelectric Division
DESIGN • ENGINEERING • PROCUREMENT • CONSTRUCTION • REPORTS







OFFICINE ELETTROMECCANICHE GALILEO

FOREIGN SALES MANAGEMENT : MILANO VIA LARGA 26 (ITALY)

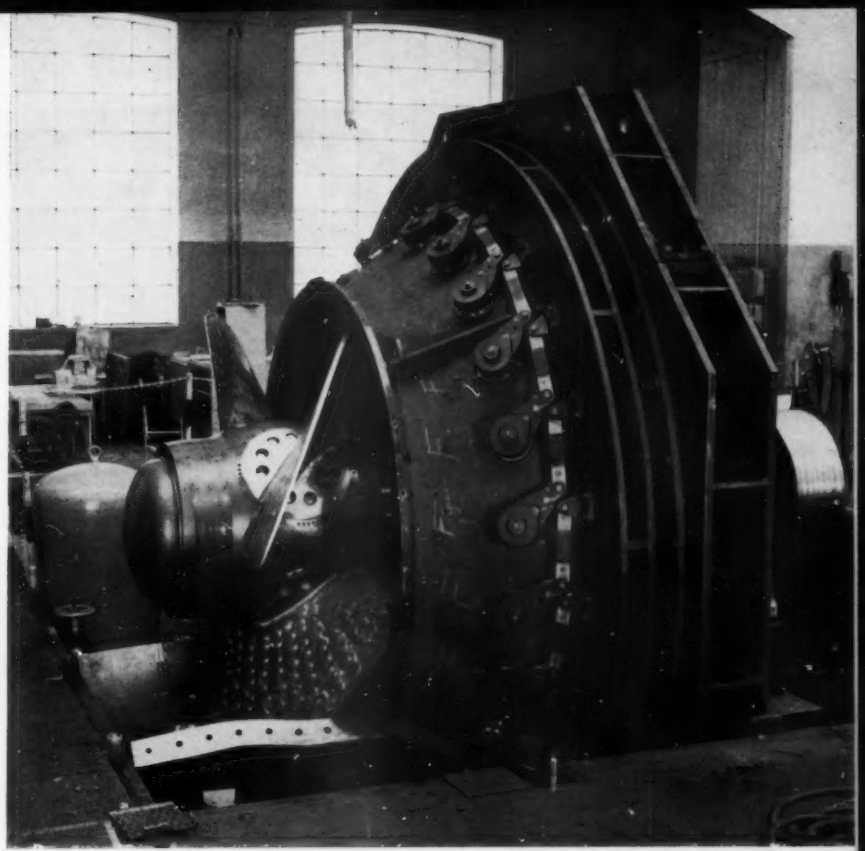
ELECTRICAL EQUIPMENT

CIRCUIT BREAKERS
INSTRUMENT TRANSFORMERS
ISOLATING SWITCHES
BUSHING INSULATORS
SWITCHBOARDS
METAL-CLAD SWITCHGEAR

FOR MEDIUM, HIGH
AND ULTRA-HIGH VOLTAGES

Sweden's first tubular turbine

now in service at Skogsforsen power station (Yngeredsfors Kraft AB)



KMW and ASEA have now completed the first tubular turbine unit in Sweden. The unit comprises in principle a horizontal Kaplan turbine with a direct-coupled synchronous alternator. The alternator is arranged concentrically in the waterway, so that the stator casing forms an extension of the internal wetted perimeter of the turbine. This setting provides a straight waterway with essentially axial flow.
Turbine output 4.875 h.p. at 14 m (46') net head and 250 r.p.m.

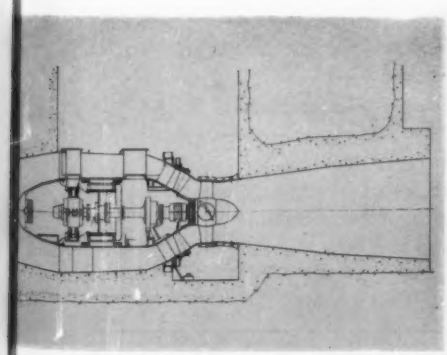
Advantages :

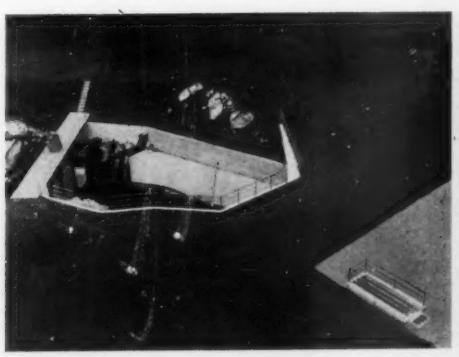
Simple design which permits wide variations.

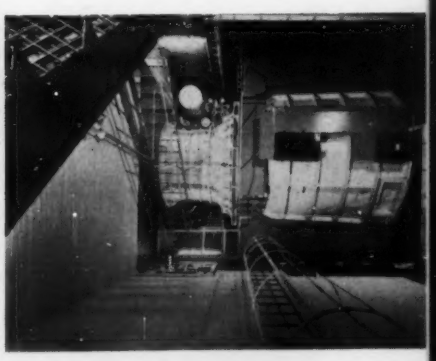
Small building requirements; the station building can be discreetly blended into the surrounding countryside.

Higher efficiency and shorter erection time than for a conventional turbine.

Permits the exploitation of power resources which had previously been regarded as uneconomical to develop.







AB KARLSTADS MEKANISKA WERKSTAD
KARLSTAD · SWEDEN

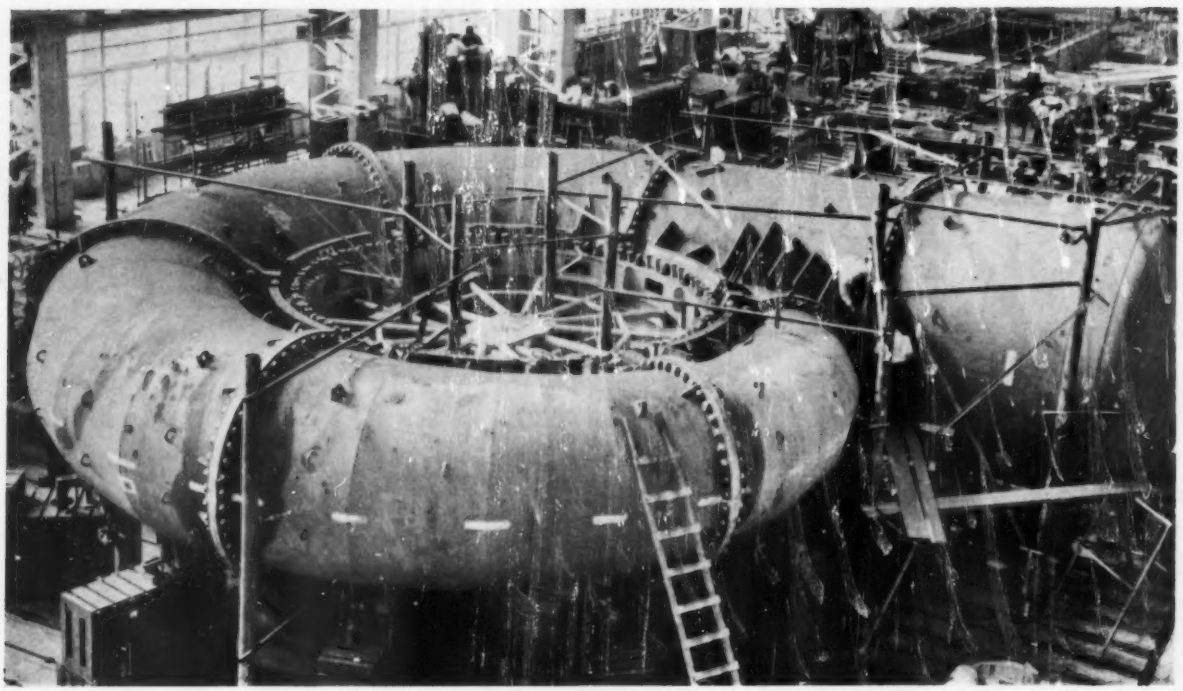
KMW

Representatives in Canada:

A. JOHNSON & CO. (Canada) LTD., P.O. BOX 56, MONTREAL 16

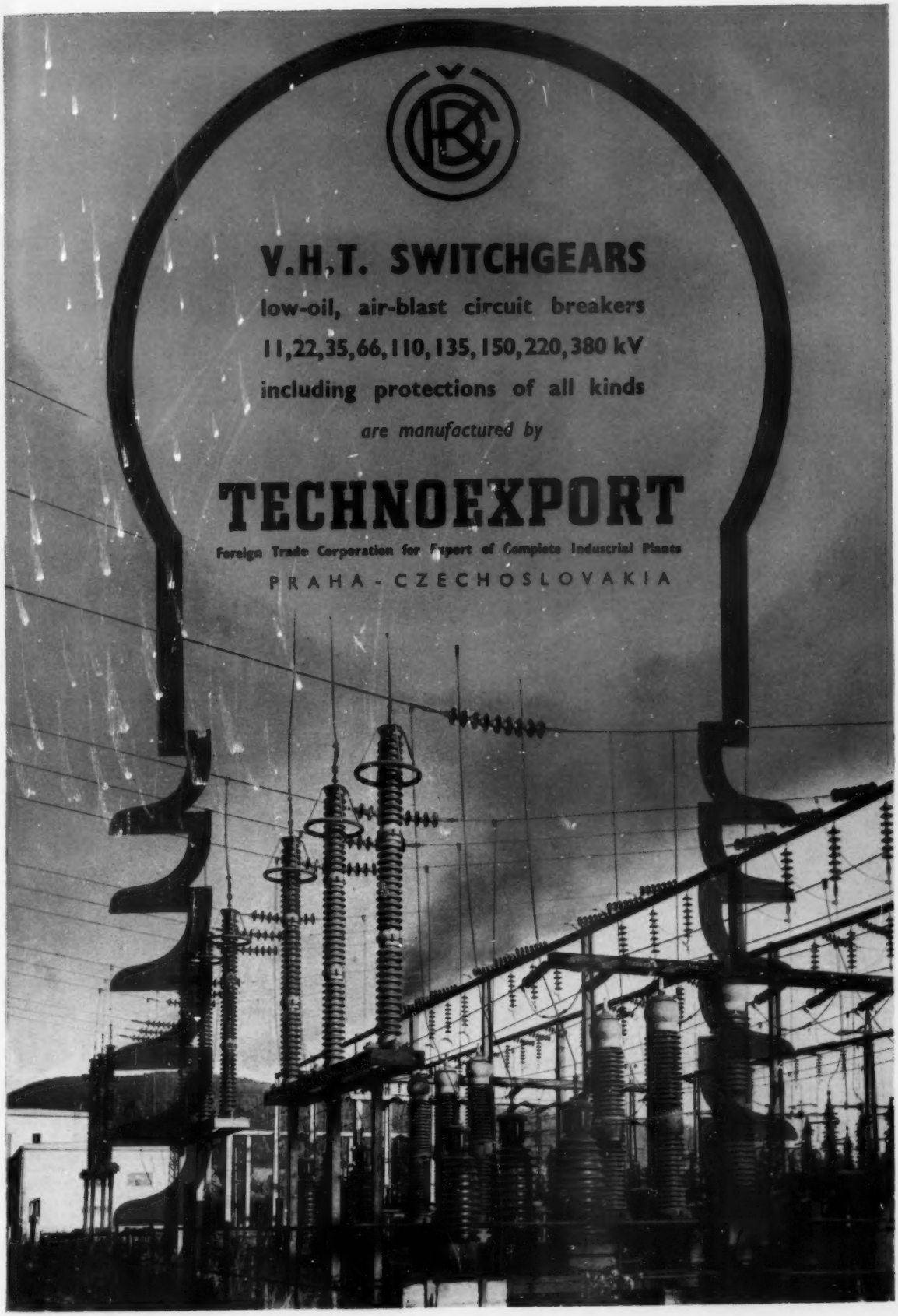
HITACHI

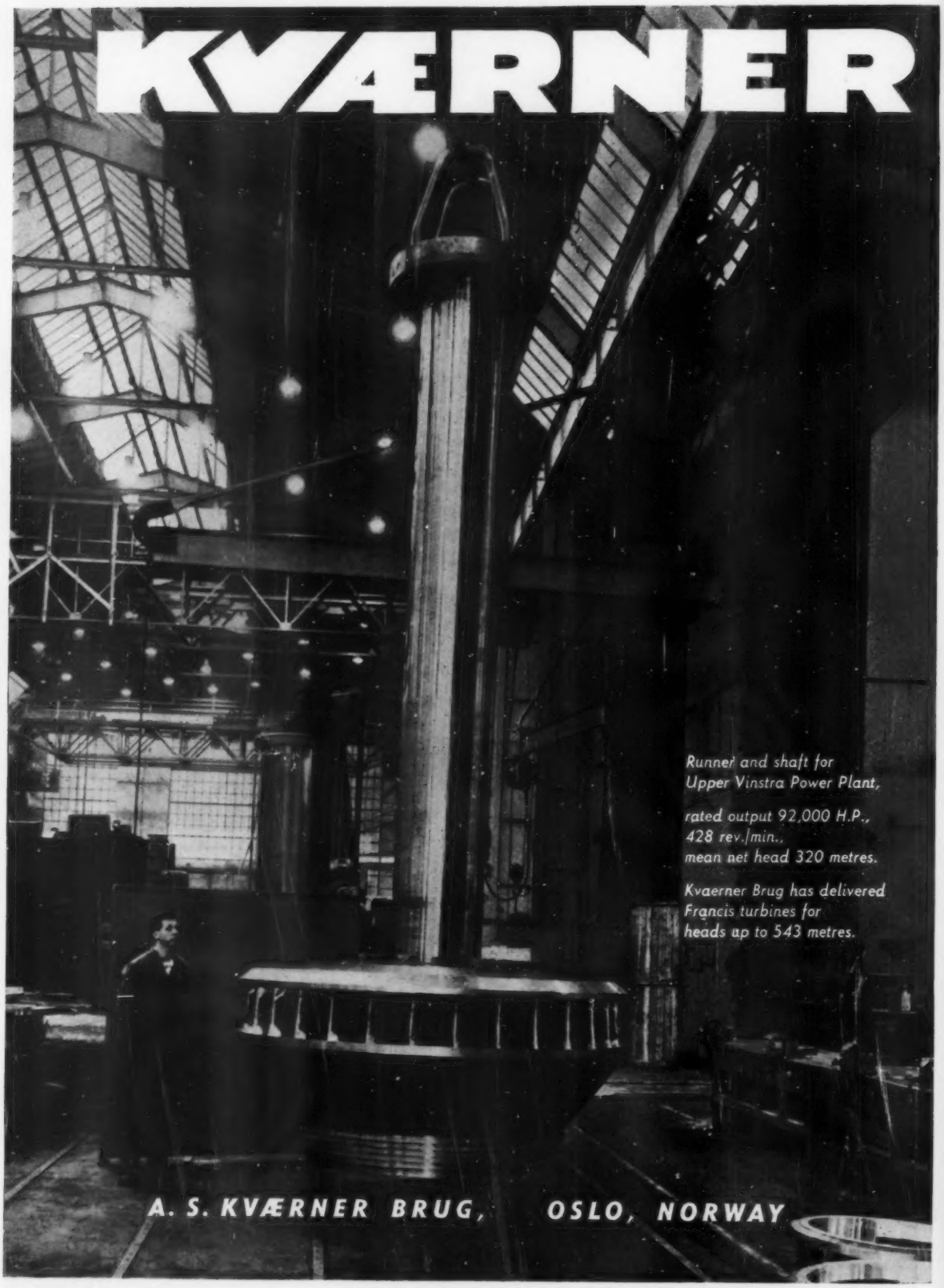
now completing the first hydraulic turbines for Thailand's Yanhee Project



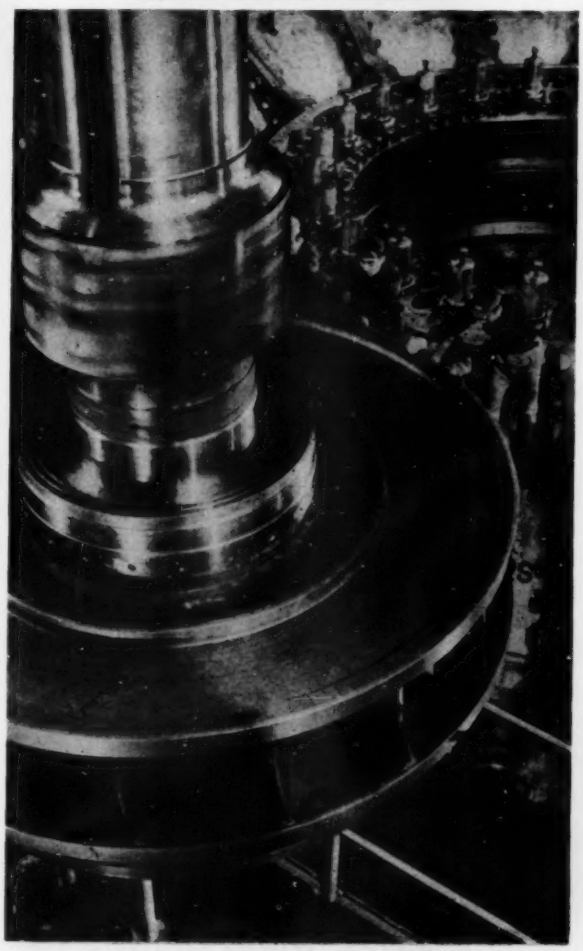
Shop tests were recently completed on the spiral casing for the first of two 115,000 HP Francis-type turbines being completed by Hitachi for Thailand's Royal Irrigation Department. These will be the first of the planned 8 sets of generating units to be installed at the downstream of the Bhumiphol Dam, as part of the Yanhee Multipurpose Project which will commence operation in 1963 and eventually supply 560,000 kW of power to Bangkok and Thonburi.
The vertical shaft Francis turbines have been designed to deliver 115,000 HP under the effective head of 112 m and for a speed of 150 rpm. Their spiral casings, with inlet diameter of 4,150 mm, will each be divided into 7 sections for transportation by barge up the Ping River to the site.

Hitachi, Ltd.
Tokyo, Japan
Cable Address: "HITACHY" TOKYO


V.H.T. SWITCHGEARS
low-oil, air-blast circuit breakers
11,22,35,66,110,135,150,220,380 kV
including protections of all kinds
are manufactured by
TECHNOEXPORT
Foreign Trade Corporation for Export of Complete Industrial Plants
PRAHA - CZECHOSLOVAKIA


KVÆRNER
Runner and shaft for
Upper Vinstra Power Plant,
rated output 92,000 H.P.,
428 rev./min.,
mean net head 320 metres.
Kvaerner Brug has delivered
Francis turbines for
heads up to 543 metres.
A. S. KVÆRNER BRUG, OSLO, NORWAY

Toshiba



Contributing to Your Better Living!

Heavy electric equipment such as Water Turbines, Generators, Power Transformers, and testing equipment for Power Stations, are being shipped out one after another from Toshiba's Tsurumi works.

Shown above is one of the 3 scheduled 133,000 kVA generators—among the largest in the world—to be installed at Okutadami Power Station in central Japan.

The 137,000 KW Francis turbine, seen at left, to be coupled with this generator is also a Toshiba product. The runner diameter of this turbine is 4,000 mm, and ranks among the biggest in the world.

Similar generators with 58,000 kVA power has been installed at Mazatepec Power Station in Mexico and is now in full operation, Toshiba is also in production for various heavy equipment for many other new projects around the world.

Tokyo Shibaura Electric Co., Ltd.

2 Ginza Nishi 5-Chome, Chuo-ku, Tokyo, Japan
Cable Address : TOSHIBA TOKYO

TO ELECTRICAL ENGINEERS LOOKING FOR THE FINEST ELECTRICAL INSULATION

PLEASE WRITE FOR DETAILS OF—

- Mica
- Micanite (Built-up Mica)
- "Paxolin" (Synthetic Resin Bonded Laminates)
- "Samica" mica paper insulation
- Glass Insulation
- Copper-faced "Paxolin"
- High Voltage Bushings
- Varnished or Impregnated Fabrics
- Vulcanised Fibre
- Leatheroid
- PVC Polythene and other Thermoplastics

"Paxolin" & "Samica" are regd. trade marks.

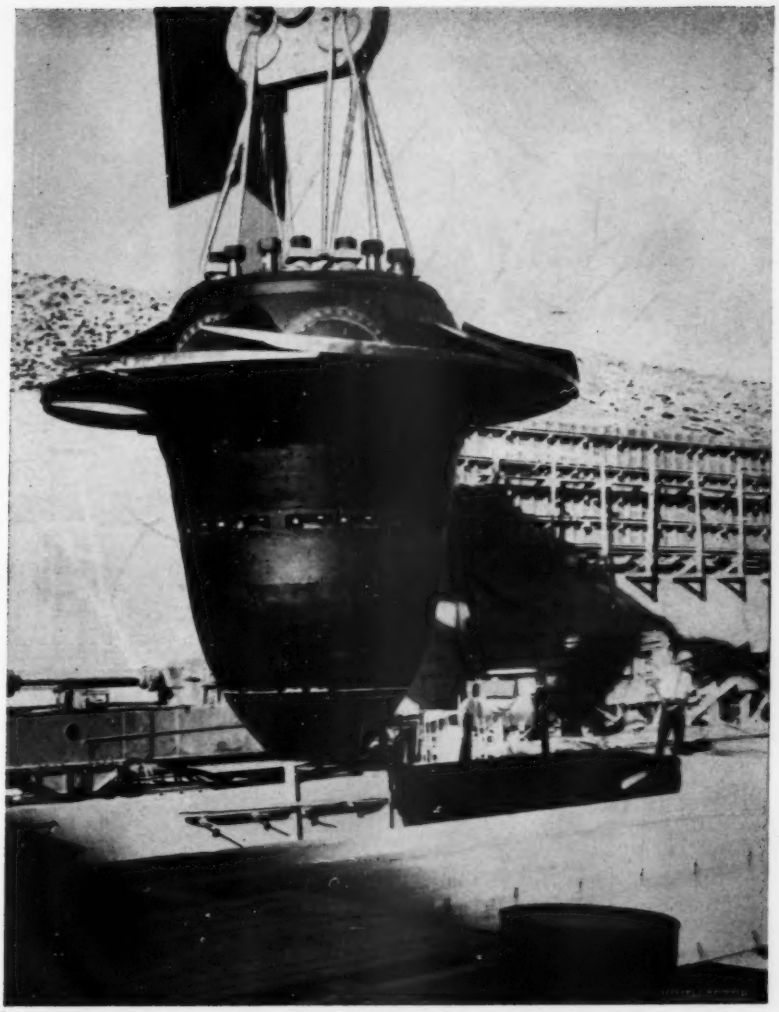
Agents in most territories throughout the World

m and i

the electrical insulation people

THE MICANITE & INSULATORS CO., LTD.,
EMPIRE WORKS, WALTHAMSTOW, LONDON E17.
TEL: LARKSWOOD 5500. GRAMS: MYTILITE LONDON TELEX. TELEX 25188.

VOITH



100,000-hp Kaplan Runner

ready for installation

in the Três Marias Hydro-Electric Power Project on Rio San Francisco, Brazil. Four such turbines with 15-foot 4-inch runners are being installed in this power station. Another four 35,000-hp Kaplan turbines with 20-foot 8-inch runners, and further two 104,000-hp Kaplan turbines with 6-foot 7-inch runners are under construction in our workshops. To this day we have built or under construction a total of 765 Kaplan turbines.

J. M. VOITH GMBH · HEIDENHEIM (BRENZ) · GERMANY

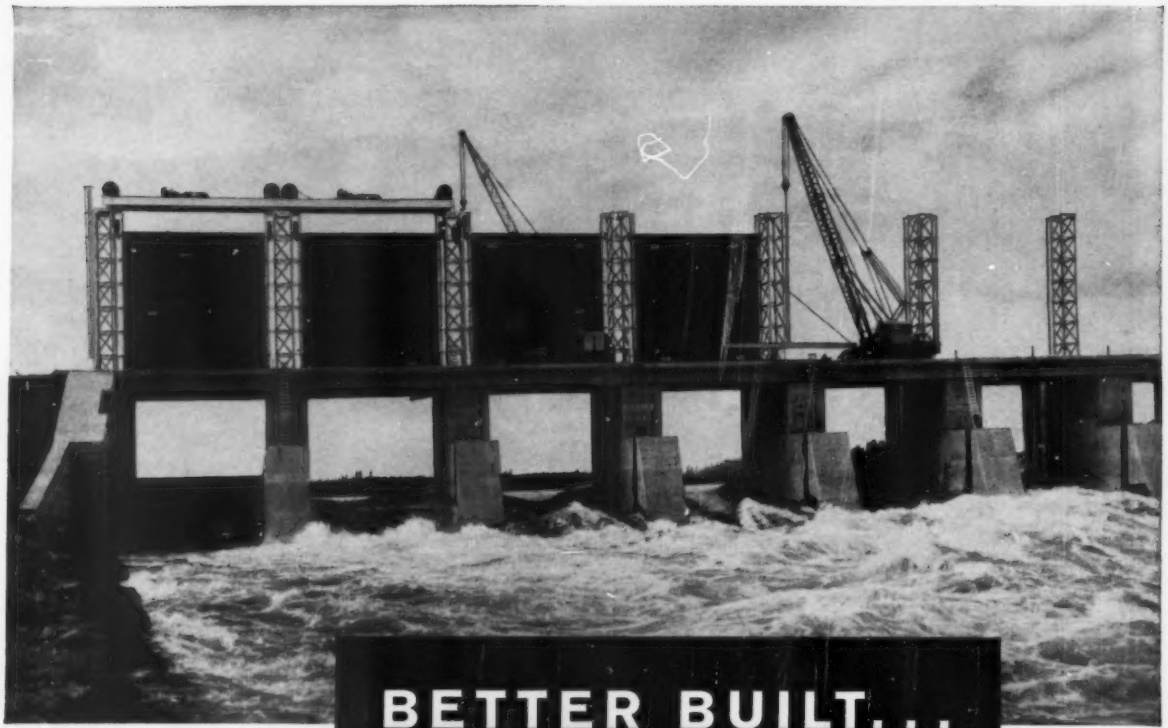


Photo by courtesy of Manitoba Hydro Electric Board.

BETTER BUILT... for better service

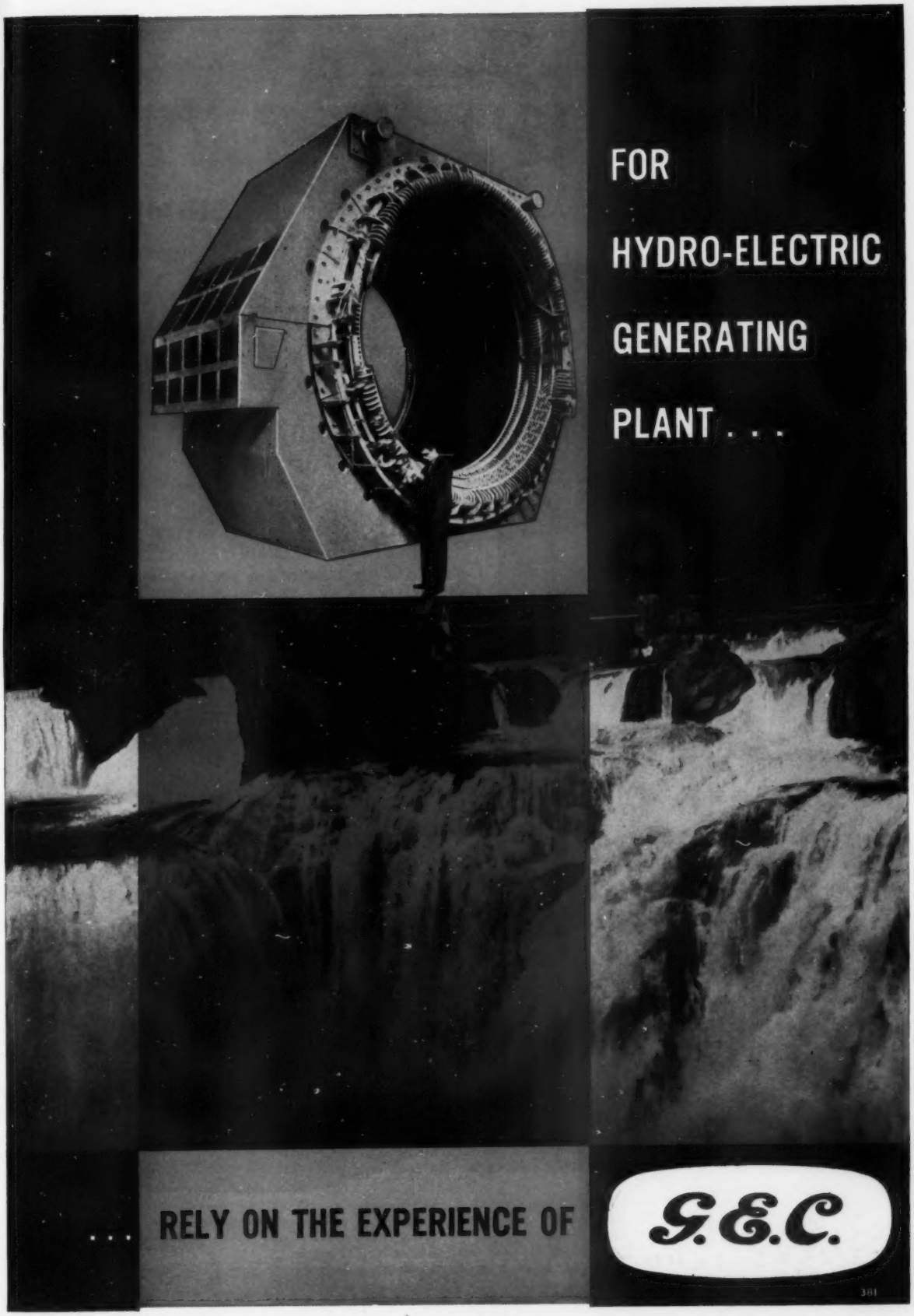
Participation in the great Kelsey Generating Station development on the Nelson River was a privilege highly prized by Canadian Vickers. Being entrusted with the manufacturing of nine Sluice Gates with Control Equipment and Embedded Parts bespeaks the confidence placed in the plant facilities, the meticulous engineering and skilled craftsmanship of Canadian Vickers Limited.

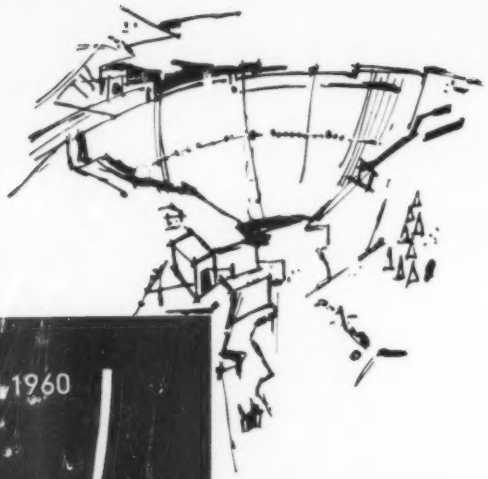
CANADIAN VICKERS LIMITED

MONTREAL • TORONTO

MEMBER OF THE VICKERS GROUP

Hydraulic Gates Of All Types • Turbines • Penstocks • Butterfly Valves • Gantry & Power House Cranes • Water Control Equipment Of Every Nature.


FOR
HYDRO-ELECTRIC
GENERATING
PLANT . . .
. . . RELY ON THE EXPERIENCE OF
G.E.C.

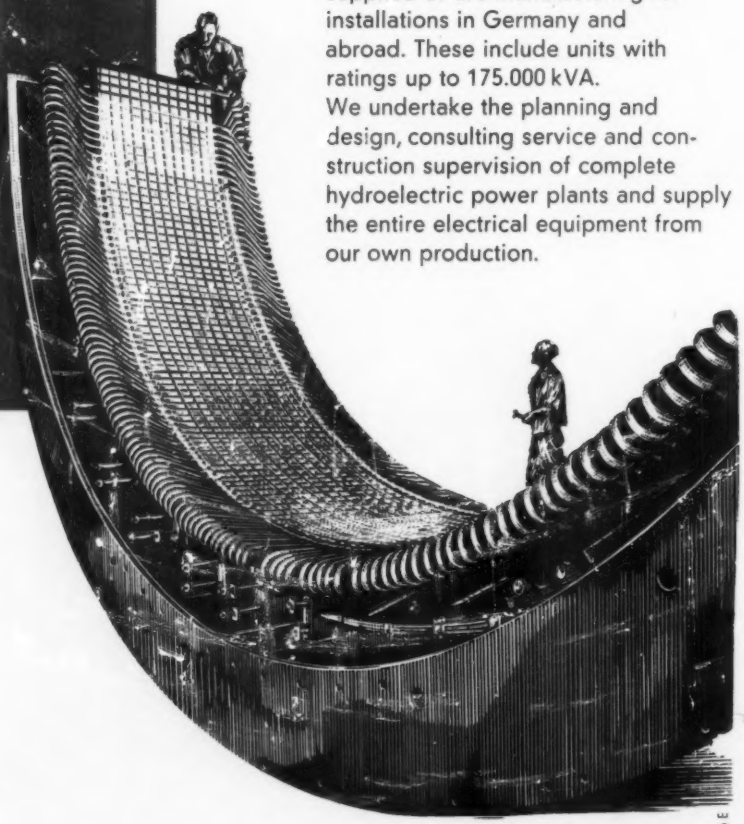


SIEMENS

The curve shows the steep rise in the number of orders placed with us for waterwheel generators in the last 60 years.

10 million kVA

is the output of the waterwheel generators which the Siemens-Schuckertwerke have supplied or are manufacturing for installations in Germany and abroad. These include units with ratings up to 175.000 kVA.
We undertake the planning and design, consulting service and construction supervision of complete hydroelectric power plants and supply the entire electrical equipment from our own production.



1/145 E

SIEMENS-SCHUCKERTWERKE AKTIENGESELLSCHAFT
BERLIN · ERLANGEN

WATER POWER

A technical journal devoted to the study of all aspects of hydro-electric development

Annually 40 shillings by post. Single Copies 2s. 6d.

Volume 13 Number 2

CONTENTS FOR FEBRUARY, 1961

Editorial: Ffestiniog Pumped-Storage Scheme - - - 45

Editorial Notes - - - - - - - 46

The Roselend Delevopment—II - - - - - 49

A Long Step Forward on the Columbia - - - - 56
By M. E. Marts

Taum Sauk Pumped-Storage Scheme - - - - 60

Advances in Low-Head Machines—I - - - - 62
By S. Casacci

The Upper Colorado River Project—II - - - - 68
By Ian B. Mackintosh, M.A., A.M.I.C.E., M.ASCE.

Ladder Drilling Technique at Inverawe Tunnel - - - 74

Short Articles: Punched-Paper-Tape Reader—Inframatic Moisture Tester—New Doulton Insulator—B.S.P. Impulse Pile Driver—Raise-Climber Method Employed at Stalon—Low-Hydrogen High-Tensile Electrode—New Holman-Iberica Factory—Euclid TS-14 Scraper 77

Book Reviews - - - - - - - 81

Abstracts from the World Technical Press - - - 82

Editor: GRAHAM R. BAMBER, B.Sc. (Hons.), A.M.I.Mech.E.

PUBLISHED BY TOTHILL PRESS LIMITED

33 Tothill Street, Westminster, London, S.W.1

Telegrams: Trazette, Parl, London. Telephone: Whitehall 9233 (24 lines)

MANCHESTER: Century Insurance Building, St. Peter's Square. Telephone: Central 7667/8/9
BIRMINGHAM: 90 Hagley Road, Edgbaston. Telephone: Edgbaston 2466, 3728 and 3732
NEWCASTLE UPON TYNE: 21 Mosley Street. Telephone: 22239
GLASGOW: 139 Bothwell Street, Telephone: Central 4646
LEEDS: 70 Albion Street. Telephone: 27174
BRISTOL: 20 Victoria Square, Clifton. Telephone: Bristol 33873

Sulzer Brothers Limited
Winterthur
Switzerland

Sulzer Bros. (London) Ltd.
31, Bedford Square,
London W.C.1

SULZER

Penstocks Storage Pumps

for hydro-electric power stations

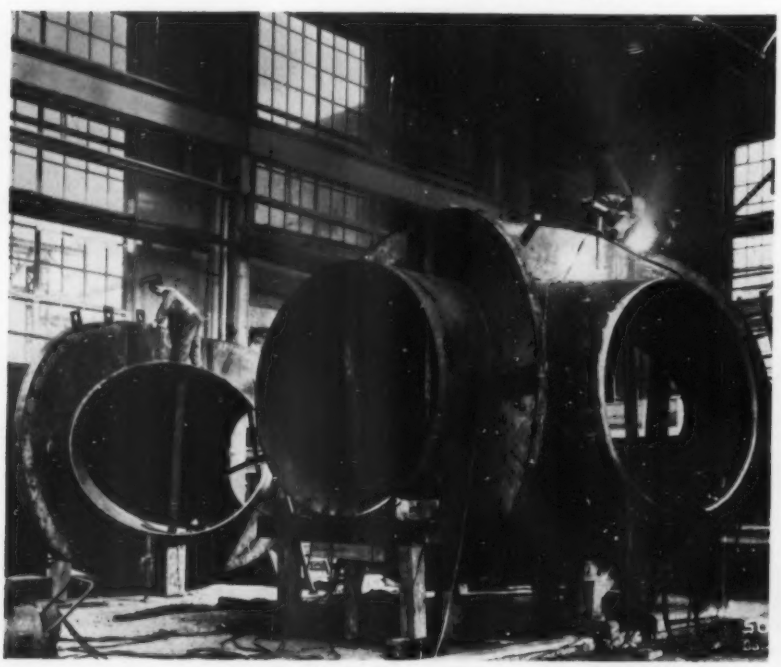
Sulzer Brothers are supplying the following equipment for the C. E. G. B. power station at Ffestiniog, North Wales:

in collaboration with Messrs. Marshall & Anderson Ltd., Motherwell

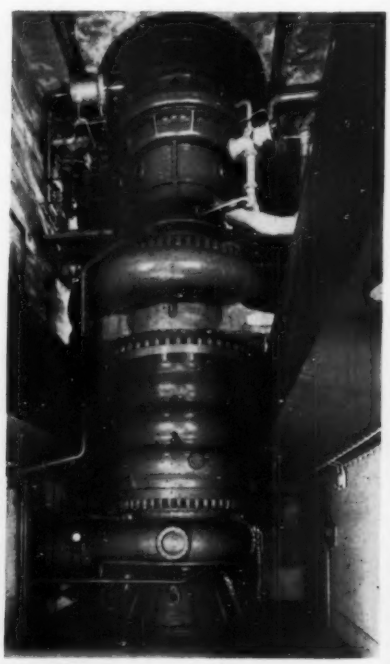
2 steel tunnel linings
4 penstocks
4 sets of branch and interconnecting pipes

in collaboration with The English Electric Co. Ltd.

4 high-lift storage pumps for the following working data:
Discharge 745 cu. ft. per sec.
Head 1,000 ft.
Max. input up to 110,000 H. P.



Fabrication of two branch pipes for Ffestiniog in the Sulzer shops at Winterthur. Inside diameter 7 ft. 6 in., service pressure 590 lb. per sq. in.



Sulzer five-stage high-lift pump in an Austrian power storage station. Discharge 49,250 g. p. m., head 3,186 ft., input 55,500 H. P.

SULZER

WATER POWER

A technical journal devoted to the study of all aspects of hydro-electric development

Ffestiniog Pumped-Storage Scheme

DURING last November the meetings in London of the senior Institutions were of more than ordinary interest to the hydro-electric engineer; for the paper on the Aswan dam presented to a joint meeting of the Institutions of Civil and of Electrical Engineers, and reviewed in these pages last month, was followed the next evening by a nominated lecture given to the Institution of Mechanical Engineers by H. Headland, M.Sc., M.I.C.E., M.I.Mech.E., M.I.E.E., entitled "Blaenau Ffestiniog and Other Medium-Head Pumped-Storage Schemes in Great Britain." Mr. Headland, who is a consultant on the staff of Messrs. Kennedy & Donkin, was responsible for the hydraulic and mechanical plant at Ffestiniog, and his lecture gave a most interesting account of the engineering considerations underlying the choice and design of the equipment.

When Ffestiniog is completed in 1962 (the first machine will be commissioned in 1961) it will have a capacity of 300 MW, and as far as we are aware it will be the largest pumped-storage plant in operation in the world until the 400-MW first stage of Vianden in Luxembourg is completed. It will also contain the largest vertical pumps yet built for 1,000-ft head.

The station is conventional in the sense that separate pumps and turbines are used, these being coupled to common electrical machines, but there are many points of interest in its design. The most economic unit capacity was found to be 75 MW. Early in 1957, when the ruling decisions were taken, these were probably the largest pumped-storage sets specified up to that time, although machines of 100-MW capacity are proposed for the North of Scotland Hydro-Electric Board's station at Cruachan on Loch Awe, and a unit rating of 175 MW is planned for the Union Electric Company's Taum Sauk scheme in Missouri. In fact, Mr. Headland envisaged the possibility of future pumped-storage sets of 200-MW capacity upwards. Vertical machines were chosen for Ffestiniog because their comparatively high speed (428 r.p.m.) gave appropriate turbine and pump settings, afforded convenient accommodation for auxiliaries, and led to an attractive building design.

The pipeline to each set bifurcates through a breeches piece, which, together with the branch pipes, is embedded in a massive concrete thrust block. Straightflow valves are used not only for the turbines but also for the pump outlets; this choice in preference to needle valves for the pumps was made after model and prototype tests.

The turbines are of the normal Francis type, rated at 105,000 h.p. over a net head range of 925–1,020 ft. The weighted efficiency at 970-ft head between 60 and 100% load is 91·6%, and the maximum efficiency is expected to exceed 93%. The pumps are of the two-stage double-inlet type. Each pump can discharge 745 cusecs against a head of 1,000 ft; at this rating it absorbs 93,600 h.p. and operates at its maximum efficiency of 90·6%. The estimated full-load overall efficiency of the station is 75·5%.

Automatic couplings were not justifiable economically, and toothed-gear couplings are used, operated by oil pressure when the set is at a standstill. The shaft assembly for each set is mounted on two thrust bearings and six guide bearings and is nearly 100 ft long.

To prevent possible damage to the reinforced-concrete floors by the expansion or vibration of the turbine and pump casings, these casings have been surrounded by a layer of microcellular expanded rubber 18 mm thick, and were set up to the centre-

READERSHIP SURVEY

To assist us in serving our profession as effectively as possible we are undertaking a survey of the readership of WATER POWER. Each subscriber will shortly receive a form asking for certain simple particulars. Your co-operation in completing this form and returning it speedily will be of the utmost service to us and will be greatly appreciated.

line in prepacked aggregate into which colloidal cement was pumped.

Automatic starting of any set for either pumping or generating is normally achieved by pushbutton from the control room, and the possibility has been kept in mind of remote control at some future date. The entire station can be brought to full-load generation in 15 min and to full pumping in 30 min.

One of the most important sections of the paper was one in which Mr. Headland discussed the general question of reversible pump-turbines and of motor-alternators. Since Ffestiniog was designed there have been rapid strides in the development of medium-head pump-turbines; a machine of this type is being installed at Providenza in Italy, and pump-turbines are also proposed for Taum Sauk to operate against a head of 800 ft, and for the underground station at Cruachan against a head of 1,100 ft. Were Ffestiniog to be designed now, reversible machines might well have been chosen, although Mr. Headland expressed the opinion that in this overground installation the economic balance and operating requirements would still have favoured separate pumps and turbines.

The author then stated some of the basic problems in the design of reversible machines. The conditions for which a high-head low-specific-speed Francis turbine is suitable call for a multi-stage pump where reversible operation is a possibility, but at medium heads (600–1,200 ft) a pump can perform efficiently as a turbine if its impeller diameter is about 40% greater than that of the equivalent turbine. In pump operation the head developed by the impeller is about half that utilised by the runner acting as a turbine, the blade loading is greater, there are flow-separation risks in the divergent water passages, and higher back pressures are necessary to reduce cavitation. Further, the optimum turbine efficiency exceeds that when pumping, and occurs at a head about 15% above, or at a speed 12·5% below, that when pumping. At optimum pumping efficiency the turbine works on a drooping efficiency curve.

This lack of correspondence between turbine-phase and pump-phase characteristics is the root problem of the combined machine, and several solutions have been proposed, including dual-speed units, adjustable guide vanes, and adjustable impeller blades. Two-speed machines are being installed at Tuscarora, but in unfavourable circumstances such machines may introduce many inconveniences in operation, and the cost and complication of the electrical machine have to be set against any improvement in performance. Adjustable guide vanes are of benefit mainly in the turbine phase, and need to be locked in the pumping phase to avoid vibration. The adjustable impeller—of which a brilliant example is the Dériaz machine, as installed at Sir Adam Beck No. 2—offers much greater flexibility of performance, but the mechanical design is more complex.

Unfortunately we have no space to comment on the author's remarks on motor-alternators, electrical starting, and braking systems, but we must mention an interesting concluding section dealing with coastal pumped-storage stations. A minimum operating head in the 500–750-ft range is contemplated, served by reversible units, and it might be possible to omit guide vanes and governors on all but one or two of the machines in a multi-unit station. In certain circumstances surge chambers could also be omitted. Sea water and wave action would introduce civil-engineering and plant problems that still await some research and investigation but should be amenable to solution.

Mr. Headland's lecture would indeed have been interesting if it had confined itself to Ffestiniog; the additional material discussing reversible machines, motor-alternators, and coastal schemes placed it in a class by itself.

Manapouri Scheme to Go Forward

IT has been announced that a major development of the aluminium industry in Australia and New Zealand is proposed over the next six years. Two companies, the Consolidated Zinc Corporation and Kaiser Aluminium and Chemical Corporation, have agreed to form a joint company for this purpose.

The project involves mining the considerable bauxite resources at Weipa, in Queensland, and the construction of a large smelter at Invercargill, near the port of Bluff, in New Zealand, as well as the expansion of the existing smelter at Bell Bay, in Tasmania. The proposed New Zealand smelter, which will have an annual output of 120,000 tons, will necessitate the development of the Manapouri-Te Anau hydro-power resources. It is reported that this is the only potential scheme in New Zealand that is likely to produce a sufficiently adequate and economic output for the smelter. The capacity of the hydro-power development in the first ten years of the programme will be of the order of 100 MW, and the estimated cost of the whole project is £100 million.

International Current-Meter Group Formed

AMONG the methods for metering large rates of flow accepted by the various national and international test codes, few have been longer established than the current-meter technique of flow measurement. In consequence, the experience available is substantial, particularly on the European Continent where this form of gauging is used almost exclusively in hydro-electric power-station measurements.

Certain aspects of current-meter performance and calibration procedure need further clarification. Researches to that effect have been in progress for a number of years in Great Britain as well as abroad, and it was with the aim of co-ordinating these that the International Current-Meter Group, ICMG, was founded in 1959. Under the chairmanship of Professor Gerber, of the Swiss Federal Institute of Technology, Zürich, representatives of seven countries drew up a complete research and development programme and reached agreement on the distribution of effort. Members meet annually to review progress and to discuss the results obtained, which are published on behalf of the ICMG by the National Engineering Laboratory at East Kilbride.

The ICMG is essentially a working group composed of experts in the field of flow measurement by means of current meters, who are directly concerned with the problems under investigation. In this it differs from the various national and international standards committees on flow measurement, with whom close contact is maintained; many delegates are also members of the Group.

It is hoped that the formation of the International

Current-Meter Group, by resulting in a deeper understanding of the possibilities and limitations of a standard technique of flow measurement, will give rise to the development of advanced methods and instrumentation. Delegates are interested in receiving information on current-meter performance or measurements of unusual interest. Contributions should be addressed to Dr. F. A. L. Winternitz, Secretary, ICMG, National Engineering Laboratory, East Kilbride, Glasgow.

Assistance for Beas Project

INDIA has now received offers of financial assistance from the World Bank and the USA for the execution of the Beas project in the Punjab. The total sum offered is $56 million.

The project, as envisaged at present, consists of two sections: the first comprises a link between the Beas and Sutlej Rivers, and a power station at the Sutlej end; the second section is to consist of a dam and reservoir on the Beas together with a power station. The Beas project as a whole is expected to irrigate 1,900,000 acres in Rajasthan and 600,000 acres in the Punjab.

Northern Canada Power Commission Report

IN the Annual Report of the Northern Canada Power Commission for the year ending March 31, 1960, note is made of the progress in the construction of the 9,000-h.p. Snare Falls development, which is some ten miles downstream of the existing Snare Rapids installation. Work on the main spillway and the erection of the power station was well advanced by the end of the period and completion in late 1960 was anticipated in the report. The year under review marked the first full year of operation of the 15,000-h.p. Whitehorse Rapids development, for which development permanent fishway facilities were largely completed, and operation of the Snare Rapids and Mayo River plants continued satisfactorily.

Further Loan for Tokke

NORWAY has received a loan equivalent to $25 million from the World Bank to give further assistance in financing the Tokke hydro-electric development. The Tokke undertaking, the largest hydro-electric power project in Norway, will consist of three power plants having a combined capacity of 810 MW; transmission lines will also be built to connect networks serving southern and western Norway and to provide a connection with the Swedish grid for the export of power.

A Bank loan of $25 million was made in 1956 to help finance the first stage of the Tokke scheme, which provided for the construction of a 400 MW plant and transmission facilities; this plant will come into operation in June 1961, six months ahead of schedule. The present loan will finance the construction of two more plants with a combined capacity of 410 MW, together with an additional 200 miles of high-voltage transmission lines.

The Tokke scheme involves the regulation and utilisation of the Tokke and Vinje river system in southern Norway. The two rivers rise in the Hardanger plateau, 3,000 ft above sea level, about 160 miles west of Oslo. Their headwaters consist of a complex of mountain lakes, several of which are being made into storage reservoirs by a series of dams and tunnels. This will permit year-round regulation of the river flow to the three power plants of the Tokke scheme.

The total cost of the new power plants and transmission lines is estimated at the equivalent of $58 million; the balance of $33 million will be met by the Norwegian Government. The works are scheduled for completion in the second half of 1964.

Japanese Hydro Progress

ONE of the largest projects in Japan, the Kurobe No. 4, is now well advanced and completion is scheduled for this year. The arch dam will be 186 m high and provide a storage capacity of 1,300,000 m^3. The underground power station, which is some 10 km downstream of the dam, will be equipped with four generators with a total capacity of 285 MW.

The Miboro dam, which is of the rockfill type, is also due to be completed this year. The dam will be approximately 130 m high and have a volume of about 7,950,000 m^3. The underground power station for this scheme will be equipped with two 125-kVA alternators.

Considerable development of Japan's abundant hydro-power resources has taken place in recent years, and, at the end of the first quarter of 1960, the country's installed hydro capacity was 10·5 million kW, which is more than half the total installed capacity of all power sources. It has been estimated that some 30% of the country's hydro-power potential has been utilised so far.

Further Proposals for the Lule River

A PRELIMINARY regional plan for the building of three power stations with an annual output of 2,600 million kWh on the upper reaches of the Stora Lule river in Arctic Sweden was recently presented by the Swedish State Power Board. The scheme, including the construction of reservoirs with a total capacity of 13,000 million m^3, would require an investment of Kr 650 million plus additional investments in transmission lines. Provided the required permits are granted by the authorities the project would be carried out in the 1960s and 1970s.

The Lule River system, including the Stora Lule River and its tributary, the Lilla Lule River, constitutes Sweden's largest remaining hydro-power resource with an exploitable potential of over 16,000 million kWh, corresponding to about one-fifth of Sweden's overall power resources. Under current schemes, including those already referred to in this note, over 14,000 million kWh per annum will be utilised in the Lule River system.

Of the 75 lakes with a total surface area of 620 km^2 existing in the region, 15 with an aggregate area of 290 km^2 will be affected by the plan. Three reservoirs with a total capacity of 7,100 million m^3 will be created by the construction of new dams entailing a considerable raising of the water levels in the lakes. The already existing Suorva reservoir will be raised by 14 m, thus increasing its capacity to 5,900 million m^3. The three power plants, which will be underground, to be built under the scheme are Vietas, Ritsem and Voujat. The largest will be Vietas, planned for an annual output of 1,130 mil-

lion kWh; it will utilise two heads, of 82 m and 78 m, the water being conducted to the plant in two tunnels, 6 km and 7 km in length respectively. The 600 million kWh Ritsem plant will utilise a head of 163 m and have a tunnel 9 km long. The Voujat station, the construction of which will not be confirmed until later, is scheduled for an output of 900 million kWh. It will have a head of 122 m and a supply tunnel 11 km in length.

RILEM Conference 1961

THE 15th meeting of the permanent committee of RILEM (Réunion Internationale des Laboratoires d'Essais et de Recherches sur les Matériaux et les Constructions), to be held in Prague from July 30 to August 6, 1961, is to include an international conference on the theme "Durability of Concretes." This will cover the following main subjects: (i) Theoretical aspects of the durability of concretes; (ii) Mechanics of the deterioration of normal concrete texture; (iii) Testing and controlling the durability of concrete; (iv) Composition of highly durable concretes; (v) Experience gained with actual concrete structures. Preparations for this conference are in the hands of Ceskoslovenská akademie věd, Ustav toeretické a aplikované mechaniky (Czechoslovak Academy of Science, Institute of theoretical and applied mechanics), Šolina 7, Prague 6–Dejvice, Czechoslovakia, to which applications for participation and full information may be directed.

First Two Benmore Turbines Ordered

THE first two 125,000-h.p. hydraulic turbines for the 750,000-h.p. Benmore power station of the New Zealand Electricity Department have been ordered from Dominion Engineering Co. Ltd., of Montreal. The Benmore station will commence delivering power by 1965, and when completed, it will be the largest hydro-electric power station in New Zealand. The Benmore development is located in the South Island near Mount Cook, and is just below the confluence of the Ahuriri and the Waitaki rivers. Since 1950, Dominion has supplied or has on order turbines for five major power stations in New Zealand, with a total of 20 turbines and a combined output of nearly 1,100,000 h.p.

Sweden Joins OEEC Power-Exchange Group

SWEDEN'S intention to liberalise supplies of electricity from other Western-European countries has been notified to OEEC by the Swedish Delegation. Sweden thus joins Austria, Belgium, France, Germany, Italy, Luxembourg, the Netherlands, Spain and Switzerland, which already freely exchange supplies of electric power. Free exchange of power between these countries takes two forms: "occasional" exchange, with the purpose of avoiding wastage of hydro-power or of providing emergency supplies to a network on which a technical breakdown has occurred; and "seasonal supplies," which electricity undertakings are not bound by contract to provide for more than six consecutive months.

In taking the decisions necessary to set up these arrangements, the OEEC Council also recommended the creation of a specialised international body consisting of the main electricity-supply undertakings concerned in such exchange. This function is at present fulfilled by the Union for the Co-ordination of Electricity Production and Transport (UCPTE), which is required to seek the most efficient use of the means available for generating and transmitting power, and to facilitate international exchange. The application of liberalisation measures and tne success of the UCPTE action in co-ordinating operations have resulted in the establishment of relations between electricity-supply undertakings in the various countries on purely commercial lines, under conditions approximating to a common market for electric power.

Sweden, a major consumer of electricity where power consumption per capita rose to more than 4,000 kWh a year, now exploits only about 40% of its economically usable water power potential. With its still large hydro reserves, which will be harnessed in the years to come, Sweden will benefit from seasonal and occasional exchanges of power, especially with countries where electricty is generated in thermal plants.

Fourth Regional Technical Conference

AT the Fourth Regional Technical Conference held recently in Colombo, it was stated that there were 103 river basins in Ceylon and for each of them a comprehensive development plan is required. It was intimated that this could be achieved by the formation of regional development organisations, such as that originally created in 1950 for the Gal Oya development. Similar autonomous development boards are to be established for river basins such as the Walawe Ganga, Mahaweli Ganga, Malwattu Oya and Kelani Ganga.

Development projects for these basins are already undergoing investigation and representatives of the World Bank are shortly to inspect several schemes, including the Walawe Ganga and Samanala Ganga. The latter project envisages a firm-power output of some 40 MW and irrigation supplies for about 40,000 acres.

Model for Dominican Republic University

THE Faculty of Engineering, University of Santo Domingo, has been presented with a working model of a typical hydro-electric installation. The model was given by Implementos y Maquinarias, C. por A., agents for Westinghouse International. The model was received by the Director of Hydraulics and Reinforced-Concrete Studies. Two large hydro-electric schemes—on the River Nizao in the south and on the River Yague del Norte in the north—are at present in the study stage in the Dominican Republic.

Inauguration of Gandhisagar Dam

THE Gandhisagar dam and power station were recently inaugurated by the Prime Minister of India, and the first stage of the Chambal multipurpose project is therefore now complete. The power station contains five 23-MW units, of which four are ready for operation. Some 920 miles of transmission lines in Madhya Pradesh and Rajasthan are approaching completion.

The first phase of the Chambal project cost about Rs. 630,000,000.

Fig. 9. Model of La Bathie machine hall

The Roselend Development

This series of articles gives a description of a large hydro-electric scheme undertaken by the Region Alpes II of Eléctricité de France. La Bathie station, described in this article, is the largest hydro-electric station in France

PART TWO

Mountain Stream Intakes

THE water supplies collected for the Roselend development come from numerous mountain streams situated high in the Alpine regions. The geological and topographical conditions require that the waters be harnessed with minimum supervision and least wastage. This requirement calls for specially designed intakes, which can withstand avalanches and which can remove sand and gravel automatically. The various streams and rivulets in the neighbouring area have 24 such intakes, and their cost amounts to less than 2% of that of the total project.

The upstream supplies comprise 14 intakes, five of which are spaced between the Mercuel and La Gittaz streams. From these intakes the water is taken by channel, pipelines and tunnels to a main collector: between the Mercuel and St. Claude, by a 90 cm. pipeline, and from St. Claude to Roselend by a tunnel which has branches of 4 to 9 sq. m. cross-sectional area for flows between 5 and 21 cu. m. The valley of the Glacier torrent is cleared by a syphon of 2·10 m. diameter and 700 m. length under a head of 120 m. Just before the syphon is a sand trap. The upstream length of the main collecting tunnel is about 30 km. The downstream supplies are those of the Ormente and its tributaries having three intakes linked by pipelines and tunnels to a collector tunnel of 5 sq. m. area under the Cormet d'Areches. The total length of the tunnel is 9 km. Its longest branch is over 6 km. in length.

In the case of the upstream water supplies and those from the Ormente, the water is not thoroughly cleaned of sand by flows into the reservoirs of Roselend and St. Guérin where the sand settles; but the intakes on the tributaries of Argentine and Bénétan are provided with special sand traps since their waters flow directly into the supply tunnel.

From past experience with water intakes from mountain streams, the maximum daily bed-load transportation should be of the order of 20 cu. m. per sq. km. of the catchment area of the stream, corresponding to flows ranging from 0·4 to 5 cu. m. per sec. For such cases it was best to adopt discontinuous gravel traps to regulate the flow with precision, and the quantity of gravel or solid matter detected depended on the size of the unit used. The continuous

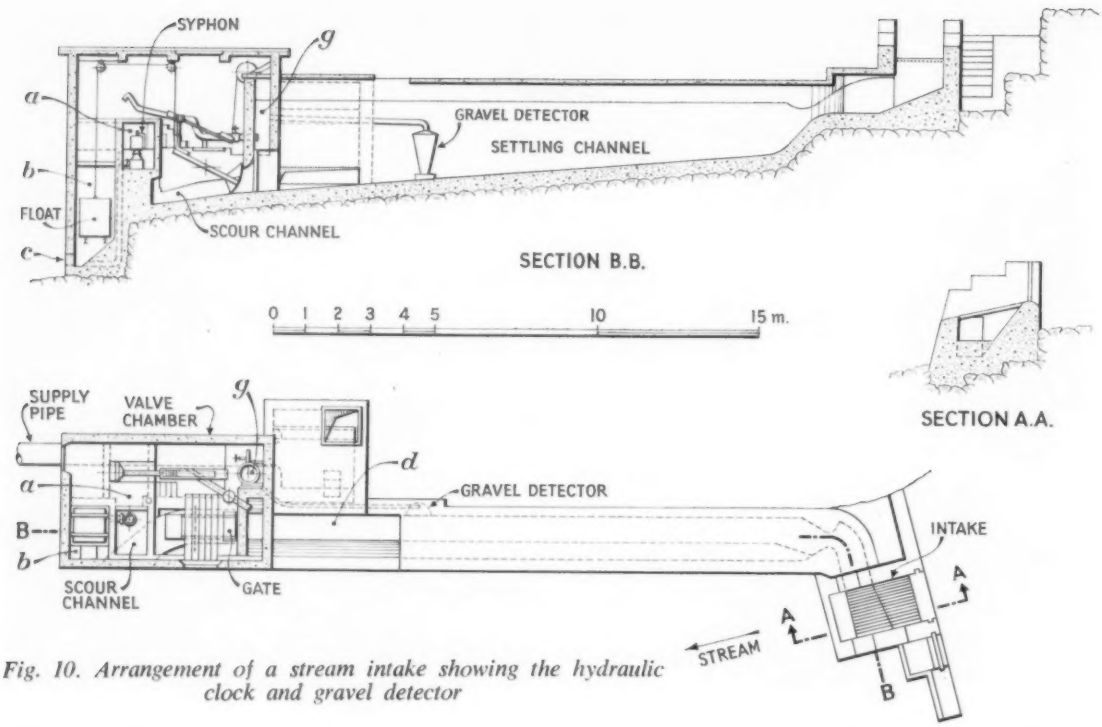


Fig. 10. Arrangement of a stream intake showing the hydraulic clock and gravel detector

type of gravel detector entails a permanent loss of water and the solid materials are brought nearer the working mechanisms. Scouring operations are not so good and from time to time a blockage is inevitable. On the other hand, a discontinuous type of detector has a simpler mechanism and involves less loss of water. For operation, the continuous gravel trap requires 10% of the flow of water and this, in fact, represents the water lost. This means that during the filling-up period of the Roselend reservoir the losses would represent about 20 million cu. m. of water or 50 million kWh in terms of power. The discontinuous trap requires only half that amount of flow for operation, and if fitted with a suitable gravel detector, the water losses may be cut to less than a quarter.

The design of the mountain stream intakes is shown in Fig. 10. A wall is built across the mountain stream and the water spills over part of it and drops into a hollow pit through a rack, the bars of which are spaced about 10 cm. apart. The water then flows into a channel having a slope of 7% and acting as a settling chamber. At the downstream end of this channel a gate blocks the flow and acts as a periodic scourer to clean out the collected silt, sand and pebbles. The cleaned water flows over a lateral spillway into an intake chamber. The scour gate has a counterweight sufficiently heavy to open it but is kept in equilibrium by a heavy float in a shaft. When the shaft is empty the gate is closed but as the shaft fills with water the heavy float is lifted, enabling the counterweight to open the gate.

The operation of the intake and its periodic scouring are automatic. Two devices have been designed to effect this: a hydraulic clock and a gravel detector.

Hydraulic Clock. The system utilises two chambers of equal volume *a* and *b*, the latter containing the heavy float. The two chambers are connected by a syphon. The chamber *a* receives water from the settling channel by a tube having an upward slope and ending with a metal box with orifices in it, which determine the rate of flow. The water level in the settling channel is controlled by the spillweir *d*. Now *a* takes a long time to fill, but when it is full the syphon acts and the water is transferred to the chamber *b* causing the float to be raised and the flushing operation to commence. The calibration of the orifices in the pipe supplying chamber *a* determines the frequency of the flushing operation, and to protect these orifices from any blockage a fine screen is placed at the lower end of the metal box which clears itself by the reverse flow of water when the level drops in the settling channel during a flushing operation.

The speed of opening of the scour gate is of importance and depends on the flow through the syphon from chamber *a* to float shaft *b*. It is necessary to utilise a syphon which would operate with very little flow, for if the flow were strong, the shaft would fill rapidly and the gate would open at such a rate as to cause temporary flooding in the stream. A pneumatic system was devised but found to be too cumbersome. Hence it is best to calculate the flow through the syphon to be such as not to exceed the stream flow by any large extent.

The duration of a flush is regulated by a discharge gate *c* which evacuates chamber *b* and must be situated at least 1 m. below the lower edge of the float. The closure of the scour gate should not take a long time as this would waste water; hence the float should move with appreciable speed down the shaft *b*. Past experience with discharge gates has shown that it is better to have a circular calibrated orifice. Nevertheless, a discharge gate is still incorporated for clearing the float chamber.

This system has proved satisfactory where the

hydraulic clock regulated the flushings to two or three times per day when the stream was running full. At times of meagre flow the flushings were reduced to once a week. The calibrated orifice and discharge gate regulated the flushing to a 12-minute duration and it was also found that after each flushing the settling channel was completely cleaned. This, of course, cuts down maintenance costs and it is envisaged that the Roselend development will require very few people visiting these relatively inaccessible points to carry out a periodical check of the water intakes to ensure the correct functioning of the mechanisms.

Gravel Detector. The gravel detector is an improvement on the hydraulic clock, which gave regular flushes even though they were not absolutely necessary—that is, the settling channel was not necessarily choked with gravel when a flush occurred and this resulted in avoidable water losses. The hydraulic clock gives a continuous but slow flow into the chamber *a* regardless of the amount of gravel trapped in the filtering canal. If some form of detecting device be installed, such that it would detect when flushing was necessary and would fill chamber *a* rapidly, the arrangement would be ideal and could replace the hydraulic clock.

The gravel detector consists of a conical funnel with its pointed end against the floor of the settling channel; it is connected to a vertical cylinder *g* by a pipe sloping upwards towards the cylinder. The water enters the base of the funnel with enough speed to draw into it gravel and sand but this speed diminishes progressively as the water rises towards the broad top end of the cone and the solid matter then drifts and settles down to block the entry to the funnel. The cylinder *g* is a simple construction elongated at its lower end where there is a calibrated orifice to give a constant leakage. Inside this cylinder hangs a float balancing the counterweight of an oscillating spillweir by a stainless-steel cable passing over a pulley. The orifice is protected by a 10 mm. mesh filter at the base of the cylinder. This oscillating spillweir connects the settling channel with chamber *a*. The water level in the settling channel and in the cylinder *g* is normally the same, but when the detector becomes choked, the cylinder empties gradually due to its permanent leakage and the water level drops. This tips the oscillating spillweir so that water from the settling channel fills chamber *a*, which then causes the syphon to function and the scour gate to be opened. This type of gravel detector has been adopted after several field tests in the course of two years.

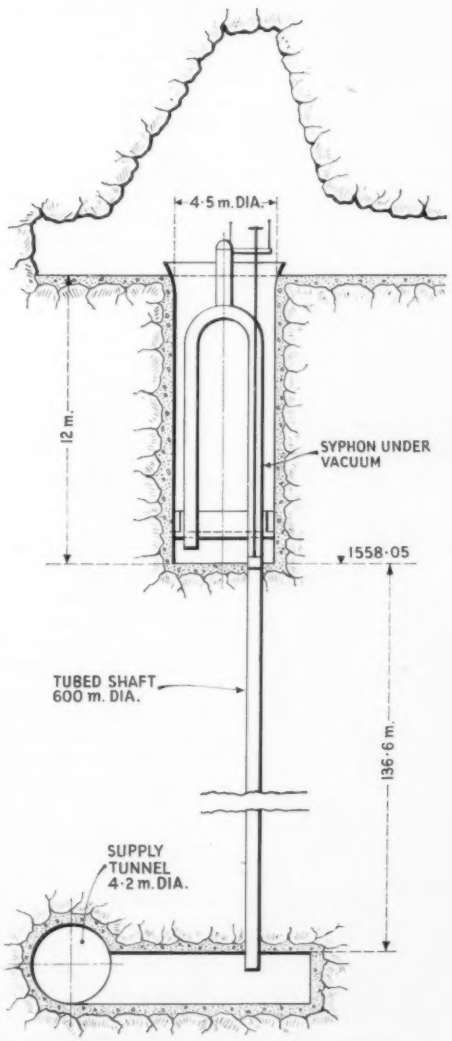


Fig. 11. Layout of Bénétan intake

Intakes from Argentine and Bénétan Streams

As will be observed from the map, the position of the Argentine and Bénétan intakes is nearer to La Bathie station than those already described. These intakes are designed to feed directly into the supply tunnel, and the water must therefore be absolutely free from solid materials.

Water from the Argentine stream is collected by two intakes and directed to a single sand trap, whence it enters a concrete-lined descending shaft of 80% slope, 223 m. long, of horseshoe section, and 2 m. in diameter, ensuring good natural deaeration. The supply from the Bénétan stream is derived by a different method shown in Fig. 11. A tubed shaft 150 m. deep and 60 cm. in diameter is sunk vertically to the supply tunnel. At the head of the shaft the tube is bent to form a syphon under full vacuum, which prevents any air entrainment into the tunnel.

Supply Tunnel

The supply tunnel to La Bathie power station is 12·6 km. long, is circular in section, and is lined throughout its length, the internal diameter varying between 4·20 m. and 4·40 m. It is under a pressure head of 130 m. at its intake near the dam and 150 m. at the downstream end. The intake is protected by a trashrack of 100 sq. m. section, and leads to two butterfly valves of 3·5 m. diameter in series, access to which is gained by means of an adit and a bridge across the gorge downstream of the dam. These valves can shut off the flow to the tunnel, which is designed for a flow of 50 cu. m. per sec., but they are controlled by a master butterfly valve 3·50 m. in diameter at the head of the penstock at the other end of the tunnel. This is done to prevent the formation of a vacuum which could cause damage to the lining.

The high pressure to which the tunnel is subjected made it necessary to have a thorough investigation of the rock through which the tunnel was to pass, paying

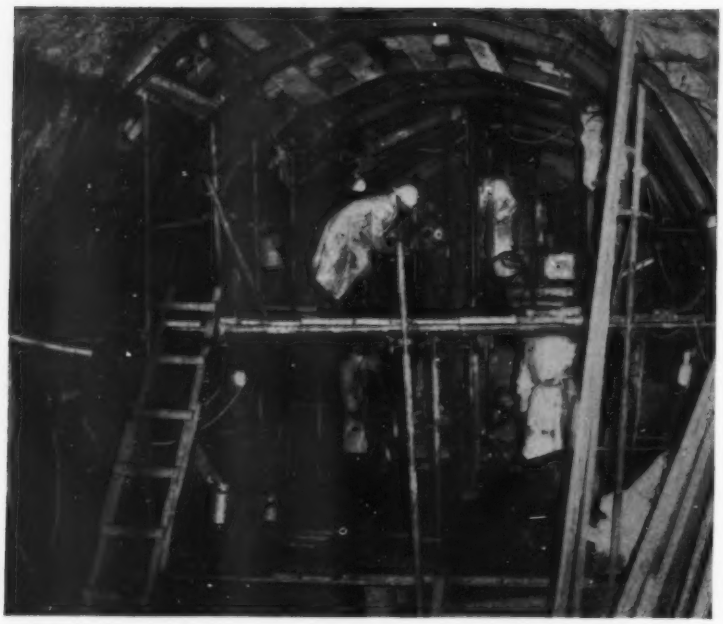


Fig. 12. Tunnelling through the Grande Combe Fault

special attention to watertightness and the need for lining the tunnel. Before the actual commencement on the supply tunnel several pilot tunnels and adits were driven for reconnaissance purposes. An adit of 350 m. and a branch 700 m. in length were drilled, at the downstream end of which investigations were made to a depth of 80 m.

At this stage it became possible to probe the most sensitive part of the tunnel track which carries the Grande Combe Fault by a tiresome but sure technique of boring. The fault consisted of coal-bearing and Trias strata over 90 m. thick between two layers of crystalline schists at levels of 1,800–2,000 m. The region, which has a draining area of 0·50 sq. km., is badly crushed and lets through water under a pressure of 15–20 kg. per sq. cm. From the Chornais adit a tunnel, driven to investigate the fault, met a cascade of water of 40 lit. per sec. To advance farther required several months of work and hence another tunnel was driven perpendicular to this fault to determine its strength.

The excavation of this part of the supply tunnel was undertaken by Entreprise Borie, who proposed to create a cover, waterproofed and strengthened around the tunnel, by silicatisation followed by cement grouting. Tunnelling was carried out in 35 m. stages and the surface was lined with reinforced concrete, 20–30 cm. thick. Waterproofing was effected by drilling a series of holes to a depth of 5 m., in the form of a halo, and then injecting a chemical solution, followed by silica gel. Then cement grout was pumped in at very high pressure.

It was also decided to have a steel lining, 12–16 mm. thick, reinforced with metal rings, in certain areas of the tunnel—about 1,100 m. in length—where the overburden is not equivalent to more than the pressure of water, and near the surge chamber. Apart from the zones treated with silicate, tunnelling progress was quite rapid, averaging between 250 and 275 m. per month, and in some cases where the rock was of good quality 300 m. per month was achieved. The poorer areas of the tunnel required some 1,500 tons of reinforced rings. The crossing of the narrow gorge of Pontcellamont was made by means of a pipe bridge, the reinforced section being 325 m. in length on each side of the bridge.

Drilling was carried out in the usual manner with a jumbo carrying the drills, which were mounted on air-legs. Mucking was carried out by Eimco 40 shovels into wagons of 3·80 cu. m. capacity, which were handled at the face by a cherry-picker.

Surge Chamber

The surge chamber is a vertical shaft of 7·5 m. finished diameter and 180 m. in height. It has a spilling-type expansion chamber of about 1,750 cu. m. capacity at its upper end and a restriction at the lower end. A butterfly valve of 3·5 m. diameter is in the hydraulic circuit immediately after the surge chamber for emergency shut-downs. The technique used to pierce this shaft from top to bottom was similar to that used for mine shafts. The lower section of the surge chamber is lined with steel backed by reinforced concrete. A model of the surge chamber was tested satisfactorily by Laboratorie Neyrpic.

Penstock

The penstock is about 2·5 km. long, has a diameter varying between 3·50 m. and 3 m., and comprises four sections.

First Section. This is 462 m. in length, 3·50 m. in diameter and passes horizontally through rock of rather poor quality. The lining is similar to that of the supply tunnel.

Second Section. In this section the conduit runs down the mountain slope for a length of 1,150 m. and is laid in a trench, embedded in concrete, and the trench backfilled. The penstock is 3·2 m. in diameter and is of the self-hooped type, the pipe being made of 54 kg. per sq. mm. ultimate strength steel and the hoops of 100 kg. per sq. mm. ultimate strength steel. The factor of safety in relation to the elastic limit is 2·2. Embedding the penstock in concrete protects it, reduces thermal variations and provides a continuous bed instead of a series of intermittent supports as with trestles.

Third section. This part consists of a steel pipe concreted solid into a tunnel 860 m. in length and inclined at 70%. The surrounding rock takes part of the pressure transmitted by the encasing concrete. The pipe is composed of two concentric envelopes; the interior is of steel of 34 kg. per sq. mm. elastic limit, and the exterior is of special steel with an elastic limit of 68 kg. per sq. mm. The method of construction is similar to that used for self-hooped penstocks. Without taking into account the strength contributed by the rock the factor of safety is unity.

Fourth section. This is formed by the distributors to La Bathie power station where they form the termination of the penstock. There are five distributors which take the form of welded-steel spheres, the largest being 4·5 m. in diameter and weighing 27 tons. These spheres are embedded in the rock by concrete.

Tests have shown that very good quality rock is to be found in the lower part of the mountain, below the 900 m. level. If the whole penstock had been underground there would have been the fear of cave-ins from the poor rock in the upper regions. This was another reason for having the penstock partly on the surface and partly underground. The penstock shaft was driven by the raising method, and already over 80% of it has been completed. The total weight of the penstock, including the distributors, will be of about 8,000 tons.

La Bathie Power Station

La Bathie station is completely underground and is at the foot of the mountains. It is designed for a flow of 50 cu. m. per sec. under a net head of 1,126·50 m. and is to be of 500 MW capacity. This is to be produced by six vertical Pelton sets, of the single-wheel two-jet type, each having a capacity of 83·5 MW at a speed of 428 r.p.m. Alongside the Pelton wheels are six three-phase transformers, four of which step up to 400 kV and the other two to 225 kV. The power is transmitted by three lines, two at 400 kV and the other at 225 kV, the grid network of Albertville. The tailrace section consists partly of an underground tunnel and partly of an open channel which returns the waters to the Isère river.

An underground station presented many advantages over a surface building, mainly from the economic point of view. The penstocks are shorter and hence there is less loss of head, and they are of reduced thickness as the rock contributes towards their strength. Further considerations led to locating the station in a stratum of good-quality gneiss and the penstocks in layers of crystalline schist. To keep the volume of excavation down to a minimum it was found to be advantageous to have the generating sets in a vertical position with their respective transformers nearby. Furthermore, this allows the station to be in two sections, the upper part being for the electrical installation and the lower part for the water circuit.

The machine hall was excavated by driving a pilot tunnel along the central axis at the level of the spring of the arch forming the roof and opening out the roof. The body of the hall was then excavated in four benches, from 7 to 9 m. thick. All the upper sections were lined with concrete without any difficulty to a thickness from 0·60 to 0·80 m. The broken rock was extracted through the access tunnel and the excavated material from the lower part was removed through the tailrace tunnels. All the excavations, including those from the tunnels and the valve chambers, amounted to about 130,000 cu. m.

To speed up the construction, the upper floors were prefabricated outside and put in place by travelling cranes. Such a method of procedure avoids the inconvenience of concreting in place and saves time in mounting equipment.

The machine hall is rectilinear and measures 130 m. long by 25 m. wide and 32 m. high, the roof being a parabolic arch of 26 m. span. Concrete walls screen off the rock walls from the interior of the station with a gap of about 35 cm. A false ceiling completely isolates the machine hall, and is also used to drain away

Fig. 13. La Bathie power station in course of construction

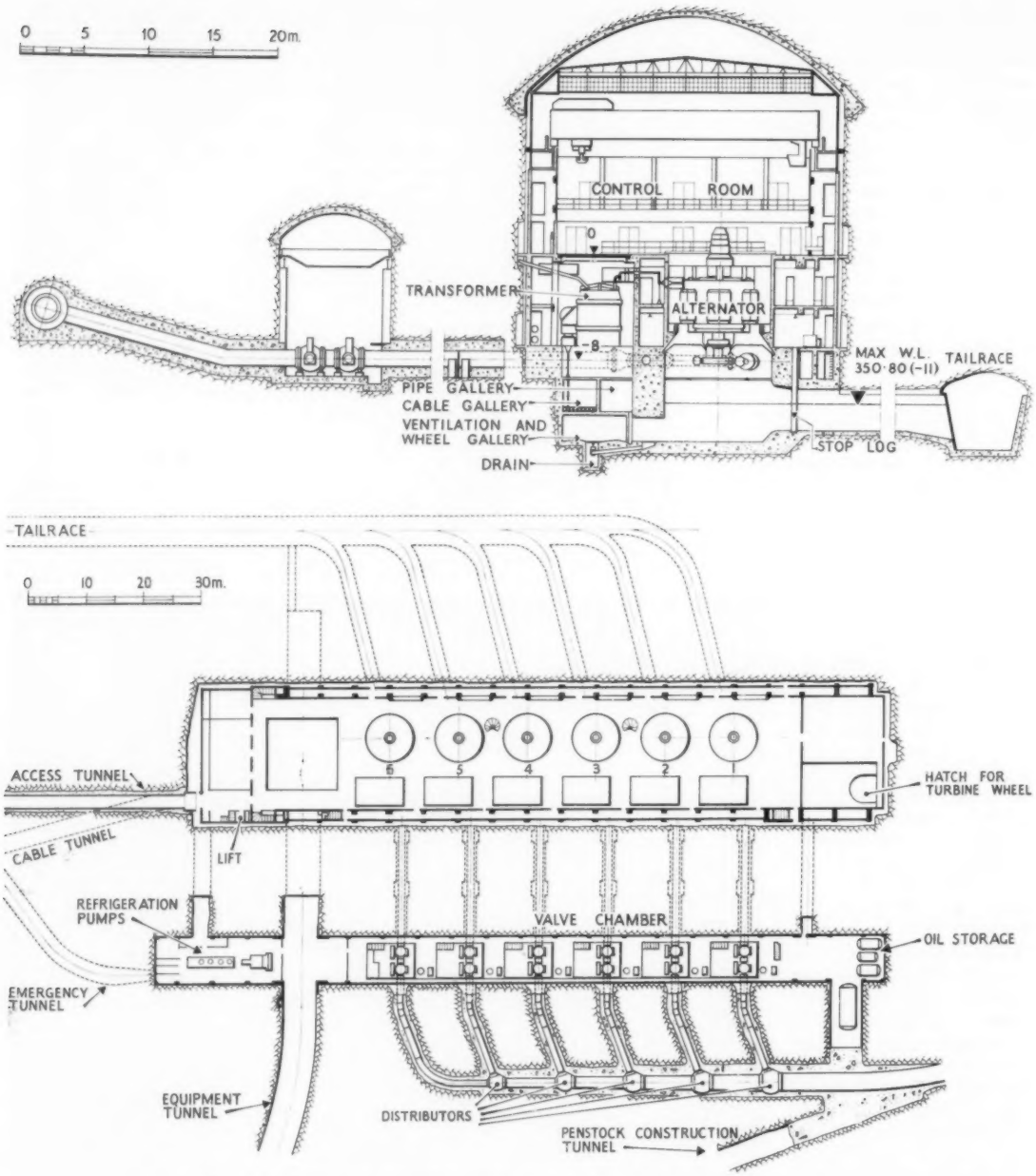


Fig. 14. Sectional elevation and plan of La Bathie power station

the percolated water and to facilitate air conditioning. The main roof arch is lined with 40 cm. of reinforced concrete to guard it against rock cracks, where the stress reaches 100 kg. per sq. cm. This would be brought about by rock falls of 45,000 kg. weight over a 6 m. length of arch. The arch is 6·5 m. high and 26 m. chord and is anchored deeply to absorb all horizontal strains. There are two travelling cranes of 100 tons capacity, the runways for which rest on reinforced-concrete supports anchored to the rock at intervals by concrete blocks.

The generating sets are arranged in a line along the hall. At the far end is a hatch covered by a water-tight door communicating with a tunnel through which the travelling cranes can remove the wheels for maintenance. A hoist on a monorail at level – 7·00 takes care of all the equipment at that level. To dismantle the Pelton wheel, a trolley of 500 kg. capacity is provided to go under the wheel as a scaffold for the maintenance crew; the wheel is brought down on another car of 25 ton capacity, by a sling passing through the hollow shaft of the generator, and then trammed to the "wheel pit" through which it can be hooked to the travelling crane.

The speed of the generating sets was originally planned to be 375 r.p.m. but was increased to 428

r.p.m. to secure economies in construction. This has enabled the alternator stators to be transported complete with their windings, and has also enabled maximum power capacity to be obtained for every cubic metre excavated.

Drainage pipes lead to a sump equipped with two discharge pumps. Above the wheel tunnel is the cable passageway for the 400 and 225 kV cables, and parallel with it are the piping and valves for cooling the machines. On the same side as the tailrace tunnel, at the elevation −7·00, are the control equipment for the turbine sets, regulation pumps, voltage regulators and 5 kV transformers. At level −3·80 are the auxiliary switchboards for a.c., and at level 0·00, that is in the main hall, are the switchboards including the protection relays, automatic relays, temperature recordings and turbine regulators. At the end of the hall, at the side of the exit, are grouped the central control switchboard and the switchboards for the auxiliary services. At the farther side there is a space for assembling the turbines and the transformers. This space will be separated by a partition 3 m. high for the storage of large items of equipment. The mounting of the equipment began early in 1959 and is progressing according to schedule.

The station is completely air-conditioned, air being drawn through the tunnel used for large equipment and passed through an air-conditioning equipment situated at the downstream end of the valve chamber. The air is cooled to its dew point, reheated to 18°C., and supplied to the station through the wheel-dismantling tunnel and other points by fans. An extractor at the top of the false roof removes air to the outside, the humidity being maintained at 60%.

The valve chamber is situated parallel to the machine hall and has a travelling crane of 40 tons capacity. A discharge channel connected to this chamber permits the escape of any water arising from a burst. In this chamber there are six sets of spherical valves, each comprising two identical valves, and also the auxiliary sets of 1,400 kVA, the supply pumps for cooling water, oil storage, air conditioning and ventilating equipments and compressed-air machinery.

Access

Access to the underground station is by a system of tunnels, the largest of which is the equipment tunnel. There is also a personnel tunnel and a third tunnel, located at the top of the arch, which was needed by the contractors to facilitate excavation work. This tunnel serves to store cooling water for the sets, for ventilation, and also as an escape tunnel in cases of emergency.

Tailrace

The tailrace conduit is underground for a length of 153 m. and then it becomes an open channel of trapezoidal section over a length of 668 m. This channel conducts the water to the Isère river and in doing so, crosses under three roads and one railway.

Acknowledgments

We are indebted to the courtesy of Electricité de France, Region Alpes II, who have supplied the details and illustrations covered by these articles. Further valuable information was found in *Construction* (February and October 1957 and July 1959), *Travaux* (August 1958), and a paper on water intakes from the IAHR Seventh Conference, Lisbon, 1958. Figs. 1 and 7 were supplied by H. Baranger, Paris.

Progress of the Works

As we go to press we learn from Ets. Neyrpic, who are supplying the turbines to La Bathie station, that the first two turbines have been running on test. La Bathie will be the largest hydro-electric station in France, and it is stated that it will be possible to render the full capacity of 500 MW available in 3½ min.

Portuguese Tunnelling Record. A new Portuguese record is claimed for rock tunnelling in the Cávado Rabagão tunnel of the Alto Rabagão hydro-electric scheme (Hidro-Electrica do Cávado), Portugal. This tunnel, which is one of many in the scheme, will have a final length of 4,900 m, of which 2,100 m have been completed. The tunnel has a horseshoe section, 4·01 by 3·96 m, and is in hard granite. All drilling was done with Holman Silver Three Handrils mounted on Holman 52 in airlegs. Three worked from invert level and three more on a rail-mounted portable staging dealt with the upper section. Air pressure at the face was 5·5–6 kg/cm². Ten men were employed at the face during each eight-hour shift. A vee cut employed required an average of 56 holes per round, each 3·2 m deep. Three rounds were fired every 24 hours but it is felt that this rate of progress could be increased by improving the mucking arrangements.

1960 WAPDA Miscellany. We have received a copy of the "1960 WAPDA Miscellany" from R. E. B. Willcox & Co., of London, who are agents for the West Pakistan Water & Power Development Authority, and at whose office copies of this publication may be seen. The annual WAPDA Miscellany is primarily intended for the layman but there is a good deal of useful descriptive matter of value to the engineer. In particular the progress reports describe very lucidly the various projects that are either under construction or under investigation and many of these projects involve hydro-electric developments. The publication opens with an interesting account of the historical geology of the Indus basin with particular reference to its effect on the groundwater and irrigation problems of today. This is followed by other articles describing in general terms the water resources of the Indus basin and WAPDA's proposed development programme, which is claimed to be one of the largest ever undertaken in the world.

The Rapier 605. A recent publication, No. 605/7, by N.C.K. Rapier Limited, of 32 Victoria Street, London S.W.1, illustrates a fine example from their wide range of excavators and cranes, viz. the N.C.K. Rapier 605. This machine which can act as a 1½ cu. yd. face-shovel, a 1¾ cu. yd. drag-shovel, a 2 cu. yd. dragline with booms up to 80 ft. long, or as a crane for loads of up to 21·4 tons, is claimed to give top work capacity over a long working life and combines reliability with low operating costs. The crawler frames of the base machine are separate units and fully tapered openings in tumblers eject stones and thus prevent fouling. A 125 b.h.p. diesel engine with electric starting is the standard power unit.

A Long Step Forward on the Columbia

An agreement has been reached between Canadian and United States negotiating teams on a plan for the international development of the Columbia River

By M. E. MARTS*

A LONG step forward in international co-operation was taken with the announcement by President Eisenhower and Prime Minister Diefenbaker on October 19, 1960, that negotiating teams representing Canada and the United States had agreed on a plan for international development of the Columbia River. Coming after 16 years of study and negotiation, the agreement sets the stage for international co-operation by calling for upstream storage and sharing of downstream benefits, and by removing the threat of diversion of Columbia-River water into the Fraser-River basin. Steps yet to be taken are the drafting and ratification of a treaty, establishment of the necessary planning and operating agencies, financing, and construction. Although the agreement is extremely significant in advancing a firm commitment to a basic international programme, it is silent or vague on certain difficult questions that must be faced, and stops short of a fully integrated international power system.

Background

The agreement has its roots in the development of the United States projects on the Columbia, beginning with the construction of Bonneville dam in the 1930s, and the subsequent failure of upstream storage supply to keep pace with the demands for downstream power generation and flood control. Although the need for storage has been emphasised by floods and recurring power shortages, the provision of storage has been hampered by a variety of conflicts of interest. In 1944, the two governments asked the International Joint Commission to investigate the possibilities of harnessing the Upper Columbia River.

Canadians recognised the potential role of Canada in the Columbia development when, in 1948, the US Army Corps of Engineers recommended Libby dam in north-western Montana as one of the major sites for power and flood-control storage. The sharing of downstream benefits became an issue when Canada asked for a permanent share of the Libby dam power output as compensation for the inundation of 40 miles of the Kootenay River Valley in south-eastern British Columbia. The United States refused to offer anything except an outright cash settlement, and the negotiations broke down.

In 1952 the Province of British Columbia indicated its willingness to allow the Kaiser Aluminum Company of the United States to build and operate a storage dam at Arrow Lakes, but the Canadian federal government viewed the arrangement as involving export of Canadian energy resources without adequate compensation, and withheld approval. The next major step came when General McNaughton, Chairman of the Canadian Section of the IJC, proposed diversion of the Columbia River into the Fraser River to emphasise the value of Canadian storage. The proposal stimulated a lively debate and analysis of the 1909 Boundary Waters Treaty. Although the treaty would permit diversion, the proposal was not taken seriously in the United States because of the fishery problem that would be created on the Fraser River and the suspected financial infeasibility of the project. However, in arguing the legality of the proposal, spokesmen for the United States emphasised the doctrine of equitable apportionment (as opposed to absolute control by the upstream state) and thus weakened the American position against sharing of Libby dam benefits. Concurrently, American agencies were meeting increasing frustration in their efforts to develop the needed upstream storage within the United States as plans for large storage reservoirs at the Hells-Canyon, Paradise, Glacier-View, and Priest-Rapids sites failed.

Although the Americans could remain unmoved by the Fraser diversion scheme, they were forced to recognise that the gigantic Peace River scheme proposed by the Wenner-Gren interests in 1958 and 1959 posed a real threat to Columbia development. Although 550 miles from Vancouver, the Peace River proposal is of such magnitude as to warrant a high transmission cost and provide all the power needed in British Columbia for years. Moreover, the Peace River scheme enjoyed the support of the British Columbia Government. With this prospect, the United States had to reconsider its assumption that Canada would develop the Upper Columbia even without any sharing of downstream benefits. Thus bargaining power was equalised, and the two countries engaged in active negotiations.

In March of 1959, the International Columbia River Engineering Board presented a report to the IJC outlining alternative plans of development, and on December 29, 1959, the IJC released its report on "Principles for Determining and Apportioning Benefits from Co-operative Use of Storage of Waters and Electrical Interconnection within the Columbia River System." Using these and other technical reports, the Negotiating Delegations, appointed on January 25, 1960, brought forward the agreement announced on October 19, which is, fundamentally, an attempt to arrive at an equitable apportionment of the water resource and the benefits.

The Proposals

The agreement is in the form of a series of proposals recommended by the negotiating teams to the two governments as the basic terms of a treaty to be drafted and ratified by legislative bodies in both countries and to remain in force for at least 60 years.

* Associate Professor of Geography, University of Washington.

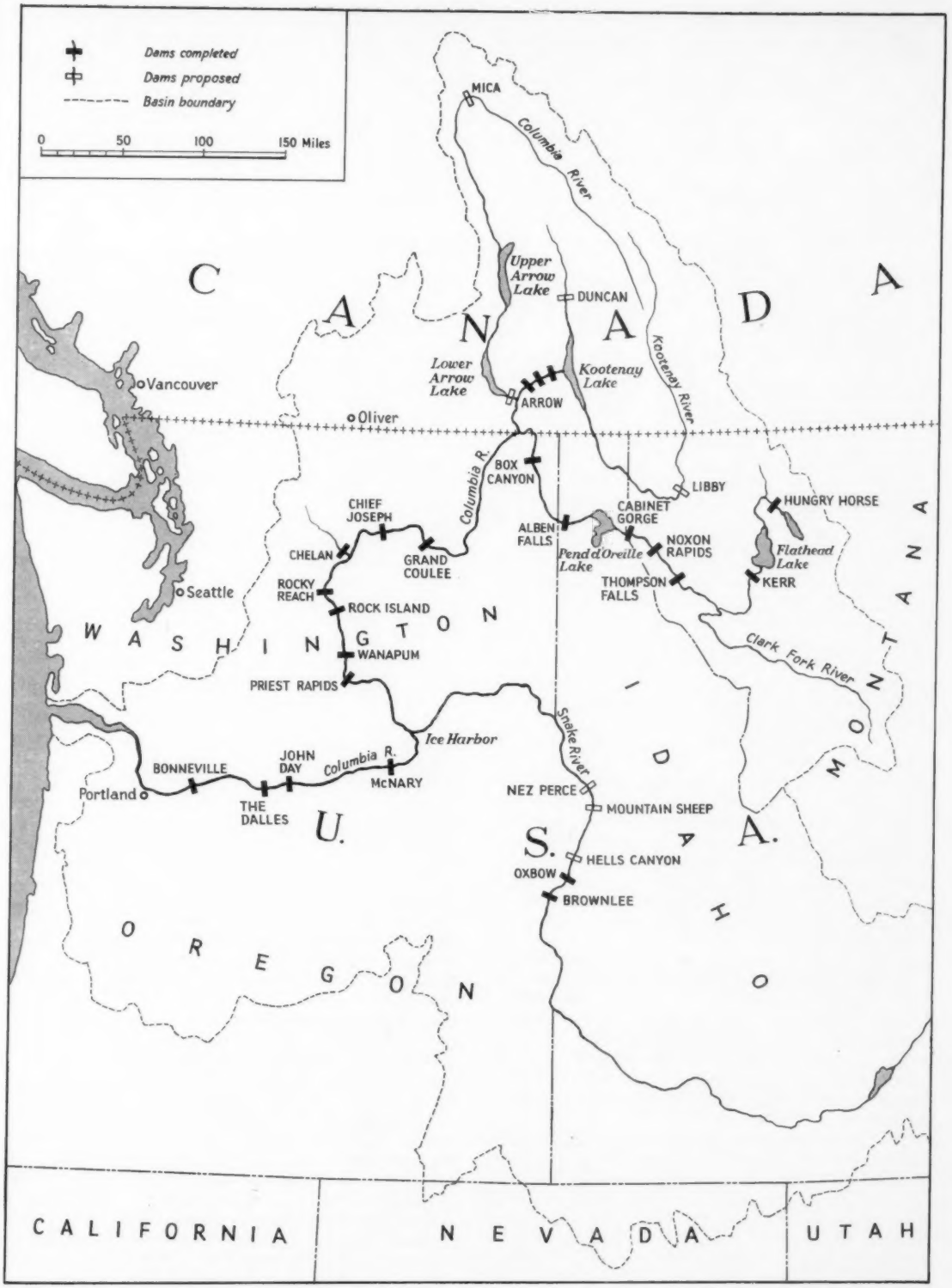


Fig. 1. Map of the Columbia River basin showing developments affected by the Canadian-US agreement

The essential proposals are as follows:

1. Canada, at its expense, will build and operate three upstream storage reservoirs, Arrow Lakes, Duncan Lake, and Mica Creek, providing 15·5 million acre ft of storage for power and flood control, within nine years following signing of the treaty.

2. Canada will receive from the United States, at the latter's expense, 50% of the downstream power resulting from use of the Canadian storage, and the United States will undertake to install the additional generating machinery necessary to make effective use of the Canadian storage. The transmission facilities needed to deliver Canada's power at a point on the international border near Oliver, B.C., will be built by the US. It is estimated that by 1970 Canada's share of the power will amount to 763 MW of average annual usable energy.

3. The United States will also pay Canada half of the flood-control benefits that accrue in the United States as a result of the Canadian storage.

4. The Canadian storage will be considered as "next-added" storage in determining the downstream benefits, regardless of the actual sequence in which additional upstream storage reservoirs may be built.

5. Portions of the Canadian power entitlement that are surplus to Canadian needs may be disposed of within the United States.

6. The United States may proceed any time within five years to construct Libby dam, and Canada will provide and clear that portion of the reservoir in British Columbia at no cost to the United States. If the United States does not exercise its option within five years, however, Canada will be free to construct whatever projects it wishes on the Canadian reach of the Kootenay River that would have been inundated by the Libby dam reservoir.

7. No diversions of water out of the Columbia Basin or from one sub-basin to another will be made during the life of the treaty, except that after 20 years (and earlier if Libby dam is not built) Canada may divert 1·5 million acre ft per year from the Kootenay River in the vicinity of Canal Flats to the headwaters of the Columbia River. Physically this is a very easy diversion to accomplish, the two rivers being separated at Canal Flats by only a mile of swampy ground.

8. After 50 years, either party may terminate the treaty upon ten years' written notice, but if no notice is given the treaty will remain in force automatically.

9. The United States will make available the existing transmission grid of the Bonneville Power Administration to provide Canada with east-west standby transmission service, for which Canada will pay $1·50 per kilowatt of dependable capacity. This service charge would be waived, however, if the two countries agree to electrical interconnection and coordination.

10. Upon termination of the treaty, nothing done under it would abrogate or modify any of the provisions of the Boundary Waters Treaty of 1909.

Other proposals deal in a generalised way with operating criteria, bases for estimating downstream benefits, provision for possible future high-cost downstream projects for which a 50-50 power distribution would be infeasible, and organisational arrangements.

The agreement provides for sharing the storage benefits, encourages but does not require full integration of the Canadian with the United States Columbia-River power systems, and requires immediate progress on construction upon execution of a treaty. The agreement marks a remarkable change in the attitudes of both countries when it is remembered that only three years ago the point being argued was whether Canada had the right to divert great quantities of water from the Columbia into the Fraser. That there still remain areas of uncertainty where questions may be raised is an indication of the complexity of the problems involved, and in no way detracts from the importance of the agreement.

Some Related Uncertainties

In a sense the agreement is really a foundation on which an international Columbia-River programme can be erected, but the programme will require many detailed arrangements and accommodations, and the solution of some vexing problems.

Foremost among the difficulties is achieving an agreement between the federal government in Ottawa and the British Columbia provincial government. Under Canadian law, the water resource belongs to the province, and the federal government has only licensing authority over export of energy. The British-Columbia Government has consistently favoured the Peace River development; the initiative for development of the Columbia River has been provided by the federal government. British Columbia, therefore, is in a position to win strong concessions from the federal authorities in exchange for provincial participation in Columbia-River developments. Minister Howard Green, Canadian Secretary of State for External Affairs, speaking in Seattle on December 1, said half-seriously that British Columbia was proving to be "tougher" at the bargaining table than was the United States. At the moment of writing the outcome of this power struggle is uncertain, but the federal government appears to have made an international commitment before having a firm arrangement with British Columbia. It has even been suggested that British Columbia's strength may be such as to allow it to construct the two lower-cost projects, Arrow Lakes and Duncan Lake, leaving the federal government to bear the cost of the more expensive Mica-Creek project. Such a move would make integration with the US Power system more remote.

A second serious deficiency in the agreement is the absence of any specific obligation on the United States to install additional generating machinery to make effective use of the Canadian storage. The agreement requires only that the United States "use its best endeavours" to provide the additional capacity. On the other hand, Canada is obligated to provide the full amount of storage within a specified period of time. Ordinarily the growth of power demand in the United States would ensure timely enlargements of the downstream plants, but this cannot be taken for granted in the event of a serious economic recession. A more cautious approach would have been to provide for the construction of Canadian storage in steps, with each step added only as additions are made to the downstream plants. The present proposal appears to leave Canada with insufficient assurance of adequate downstream benefit, even though the formula may be equitable.

The uncertainty about additions to capacity at downstream plants also introduces the related question of the forecasts of future power demands. The proposed storage is assumed to be needed for "normal" load

growth; subnormal growth would result in international fiscal embarrassment. Again, step development would appear to offer a safeguard against any lag in the demand for power.

The future market for Columbia-River power in British Columbia will be greatly affected by the Peace-River proposal. If the Peace-River project is built concurrently with the Upper-Columbia programme, British Columbia may face a large power surplus for some years. The Peace-River development is proposed as a private venture, and the Upper-Columbia programme is regarded as a government venture, so that a choice between the Peace and the Columbia is viewed by many as a private versus public ownership controversy. It would be awkward politically for a government to attempt dissuading the Peace River Development Corporation from its intention to build the mammoth project. There is real prospect, therefore, of a rather serious power-marketing problem in British Columbia. It is interesting to note that this agreement permits export of power to the United States, which suggests a reversal of the Canadian policy to discourage energy export.

Another problem involved is the conflict between on-site power at Mica Creek and releases of Mica storage to meet the Canadian commitment to the United States. Releases of storage during the winter drawdown season mean, of course, loss of head for the remainder of the season. Although this problem is inherent in all storage-power dams, it is aggravated because of Mica's size and cost, its location at the upper end of the system where inflow is small relative to the size of the reservoir and transmission is costly, and particularly because releases from Mica storage will be made for a foreign power system, not for a British-Columbia system of which Mica is a key project. There are several possibilities which could ameliorate the operating conflict at Mica. An on-site power plant might not be constructed at Mica, but many government statements have encouraged the Canadian public to expect not only power but low-cost power from Mica. If the United States does not exercise its option to construct Libby dam, Canada could proceed with the Canal Flats diversion combined with storage above Mica, which appears to be an economical method of increasing the water available at Mica. Or if the Canadian and United States plants are integrated into one superpower system, the full credit which Mica would receive for its storage releases would compensate for the sacrifice of on-site power.

The inclusion of Libby dam in the agreement may prove to be an important concession by Canada and perhaps even a luxury to the United States. Libby requires both a high dam and expensive relocation of several towns and industries plus over 50 miles of mainline railroad and highway. The alternatives to Libby include the Canal Flats diversion and at least two reportedly advantageous dam sites on the Canadian portion of the Kootenay River. These alternatives would provide more power to Canada than would Libby, as well as enhancing the Mica output as discussed above. The reasons for the Canadian acceptance of Libby are not clear, especially if the hints that the US negotiators were willing to forego Libby are true. The answer may lie in the existing plants of the Consolidated Smelting and Mining Company on the Lower Kootenay, but these plants will also benefit from Duncan-Lake storage and must be rebuilt if they are to utilise both Libby and Duncan-Lake storage effectively. Or the answer may be simply that the cost of the alternatives to Libby may have been more than Canada wished to invest.

Still another uncertainty concerns the need for arrangements to recover downstream benefits from nonfederal plants in the United States and the private Canadian plants mentioned in the preceding paragraph. One of the proposals prohibits the use of the improvement in stream flows brought about under the agreement by any entity, except with the approval of the operating agencies designated by Canada and the United States.

Presumably an international treaty would suffice as the legal basis for recovering downstream benefits from existing plants, but it is doubtful that even a treaty would provide authority to require plant additions that might be needed to make full use of the Canadian storage.

A final problem to be noted is that the sponsors of potential projects now being planned in the United States are placed in an equivocal position by the agreement. If the agreement is implemented, a substantial part of the region's future power needs can be met from the international development. Yet until this international development is implemented, the need for meeting the increase in the demand for power remains. If the international agreement proceeds to the implementation stage without delay, the uncertainty in planning alternative developments will be minimised. If, however, implementation is delayed, a paralysing effect of serious dimensions will be felt in efforts to keep regional power supply in balance with demand. As an example of this uncertainty, Interior Under-Secretary Bennett, who was chairman of the US negotiating team, has stated that the agreement makes both of the two dams involved in the current controversy on the middle Snake River, High Mountain Sheep and Nez Perce,* unnecessary. His view has been challenged by sponsors of both projects, so it is obvious that expert opinion is varied. The result will likely be a tendency to wait-and-see, especially when difficult decisions, perhaps prejudicial to fishing resources, would otherwise have to be made. An effect of this power-planning problem is that the position of those seeking to protect fishery resources on rivers important for salmon spawning is strengthened.

Summary

The agreement, though not solving all aspects of the complex problem of Columbia-River development, is a long step forward and will serve as a model for future international developments. The problem was more complex than that posed by the St. Lawrence development, because of the relationships between upstream storage and downstream benefits, and the related problems posed by changes in the total system of projects as time goes on. The essential criterion in reaching agreement was mutual benefit, and the critical element was quality in bargaining strength. The agreement provides for hydraulic integration and opens the door to full electrical integration. By providing the needed upstream storage, Canada benefits from the earlier and lower-cost power plants on the US portion of the Columbia. Both countries will gain from the co-operative arrangements called for by this agreement, and their gains can be maximised by joining in a fully integrated system.

* WATER POWER, January 1961, p. 23.

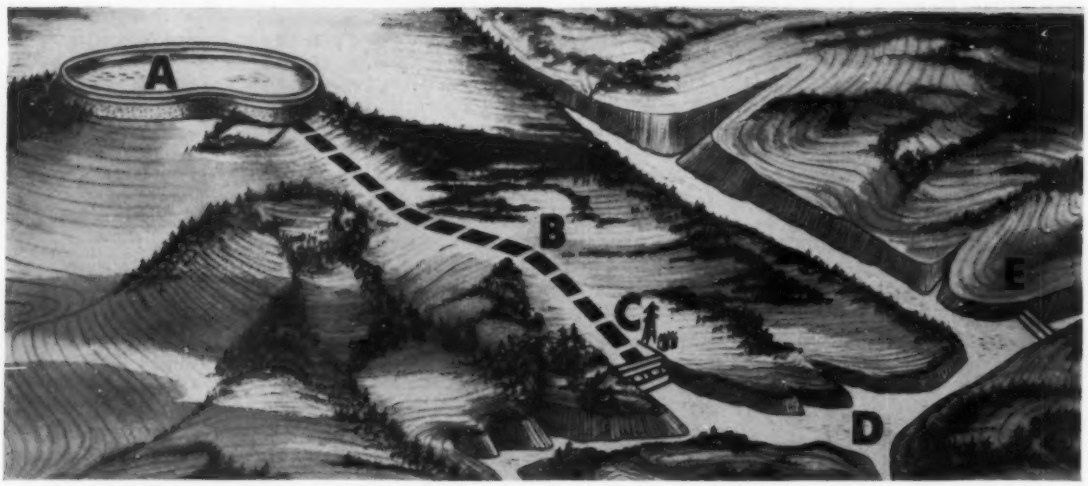


Fig. 1. Sketch of the Taum Sauk scheme. (A) *upper pool,* (B) *tunnel,* (C) *power station,* (D) *lower pool,* (E) *dam*

Taum Sauk Pumped-Storage Scheme

The Union Electric Company has commenced work on the largest pumped-storage plant in the United States. It will have a capacity of 350 MW and is scheduled for operation in 1963

THE Union Electric Company of St. Louis, Missouri, has commenced work on a pumped-storage plant which, when completed in 1963, is expected to be the largest in the United States. It will have a capacity of 350 MW, and will be a pure pumped-storage installation, its purpose being to furnish day peaking power to a system served primarily by high-capacity high-load-factor steam stations. Particular interest attaches to the machinery, which will consist of two 175-MW pump-turbines operating under a head of 800 ft. This is indicative of the advance made in recent years in pump-turbine design, for earlier practice would undoubtedly have favoured separate turbines and pumps for this capacity and head.

A study of possible sites for a pumped-storage plant was commenced in 1953. The first to be investigated was on the shore of the Lake of the Ozarks, where a large upper lake could be formed providing a head of 160 ft and sufficing for a plant of 300–500 MW in capacity. This proved to be uneconomic in view of the size and cost of the machinery and structures required for the comparatively low head and the great distance of the site from St. Louis.

A survey was then made of all possible sites within the region of St. Louis offering heads of 300 ft and upwards, and about half a dozen sites were studied in some detail. In 1955 a complete analysis was made of a site on Establishment Creek, in St. Genevieve County, but it was found that geological conditions were unfavourable, that the value of the farmland to be inundated was high, and that a plant capacity of over 750 MW would be needed to make the site economic.

By this time it had become evident that the conception of a large upper storage lake retained by a high rockfill dam, and providing a head limited to 300 ft, was inherently uneconomic in the prevailing conditions, and that the solution lay in the use of a much higher head. This would permit the construction of an upper pool of much smaller volume, involving less-expensive earthworks, and would enable high-speed high-capacity machines to be installed.

A site complying with these revised conditions was eventually found near Taum Sauk Mountain in the Ozark Mountains 90 miles south-west of St. Louis, where the East Fork of the Black River forms a convenient site for a lower reservoir. To form the upper reservoir it was decided to cut off the top of a nearby 900 ft granite peak and to use the spoil to build an elliptical embankment 100 ft high, impounding 4,000 acre ft of water at a level of 800 ft above the lower pool. The lower pool is to be formed by a concrete dam 360 ft long and 60 ft high, impounding 6,000 acre ft.

A tunnel 6,800 ft long will connect the upper pool to the power house. The upper reach of 5,300 ft will be 26 ft in diameter, except for the uppermost 375 ft, which will be enlarged to take a 2 ft concrete lining to prevent seepage. The lowermost 1,550 ft will be 18 ft 6 in in diameter and will be steel lined.

No details of the mechanical and electrical plant are available beyond the fact, already mentioned, that there will be two pump-turbine units, each rated at

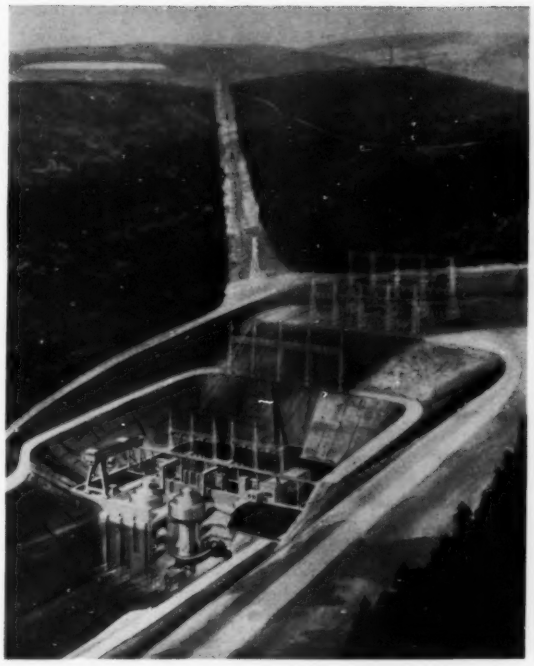


Fig. 2. Wash drawing of the Taum Sauk pumped-storage station and upper pool

Fig. 3. Aerial view of the site showing work in progress on the construction roads, the upper pool (A), the power-station site (B), and the lower dam (C)

175 MW. A transmission line will connect to a junction point 30 miles away.

The minimum dry-weather flow of the Black River of 5 cusecs is sufficient to fill the lower reservoir twice in a year, and as the only losses in the pumped-storage circuit will be evaporation and seepage, the water supply to the plant will be assured and the normal flow of the river will hardly be affected once the reservoir is filled. The storage in the upper reservoir is equivalent to 2,750,000 kWh, of which 2,200,000 kWh will be used in a normal day's operation. Pumping will be carried out at night, and will absorb power at rates up to 400 MW.

The decision to proceed with the Taum Sauk scheme was taken in the late summer of 1949. By that time it had become imperative to arrange for additional system capacity, and the choice lay between the pumped-storage scheme and a steam power station. On the basis of firm tenders it was found that the construction cost favoured Taum Sauk, and it has been possible to defer the construction of a new steam station for two to three years.

The basic features of the scheme were determined by the Union Electric Company's engineers, but Sverdrup & Parcel, Consulting Engineers, of St. Louis, have been retained to finalise the design of the structural and civil-engineering features.

Use of Underwater Television in Scotland. A Marconi-Siebe Gorman underwater television camera, to be used for research into fish and hydraulic problems, has been ordered by the North of Scotland Hydro-Electric Board. Among other things, the camera will be employed for the inspection of the fish screens which prevent smolt from being drawn into the turbines. Inspection of these screens was previously carried out by divers. The camera will also be used to study fish behaviour in the fish passes and to inspect the tunnels linking the dams and power stations. It will thus be possible to examine the condition of the tunnels without the expensive procedure of dewatering.

The Hydro-Electric Board have already carried out tests with underwater television equipment, using the camera to inspect fish screens down to 120 ft below the surface. It is claimed that the 14 in monitor supplied with the camera showed greater detail in murky water than could be seen by a diver.

Portable Compressors. A brochure describing their full range of oil-flooded rotary portable Power Vane compressors has been issued by the Consolidated Pneumatic Tool Co. Ltd., of 232 Dawes Road, London, S.W.6. The first section describes in detail the operating principles, design features and constructional details of the range, and this is followed by a section in which specifications and illustrations are given of units in the range from 125 to 600-c.f.m. capacity. Of particular note are the details of the new 125 and 260-c.f.m. models, which the company has recently introduced. The company's Land-Rover-mounted unit was described in the November 1960 issue of WATER POWER.

Ferranti Limited. A pamphlet entitled Classified Index of Ferranti Computer Literature contains a complete guide to the literature available from their London Computer Centre, 68/71, Newman Street, London, W.1.

Advances in Low-Head Machines

New possibilities in the development of low heads, whether for run-of-river or for tidal plants, are opened up by the advent of the large axial-flow bulb-type machine. This series of articles discusses the development, design and construction of these machines, and this first article is concerned with the earlier small sets, which provided the experience on which the design of larger units has been based

By S. CASACCI*

PART ONE

THE development of hydro-electric resources depends on the technical and economic climate of the particular period and of the particular country. In industrial regions the harnessing of the high- and medium-head falls is already approaching completion, and for these countries low-head sites form the most important part of the hydraulic resources not yet developed. For heads below 15 m the cost per kWh naturally increases rapidly as the head diminishes, and low-head plants therefore call for a close study of all technical solutions capable of enhancing their profitability. The cost of these installations depends largely on the civil engineering (dam, power station, etc.) and can be substantially lowered only by designs that offer a simultaneous reduction in the cost of the civil engineering and of the mechanical and electrical equipment. New designs incorporating axial-flow units will greatly improve the economy of low-head installations and will have repercussions even on the classical Kaplan plant.

If frequency regulation is not required, the simple and robust mechanical design and the moderate bulk of sets with upstream-bulb generators can usually bring about an important reduction in the overall cost of the installation. In the case of low-power sets, which form the subject of our immediate study, an induction generator is direct coupled to the turbine and revolves in oil which also forms the cooling medium. For larger powers, where a direct-coupled machine is used, the generator revolves in atmospheric or compressed air.

If the machines have to undertake frequency regulation, two solutions are possible. For large installations stability could be secured by conveniently located synchronous condensers. In cases where the machines themselves have to maintain stability, the provision of the necessary inertia leads to overall dimensions that impair the attractiveness of the direct-coupled bulb-type alternator. The increase in the external diameter of the alternator, and consequently in the diameter of the waterway, leads to an increase in the centre distance between sets, so that one of the advantages of axial machines disappears. An economic solution consists of driving the alternator through a speed-increasing gear. Numerous investigations and actual installations are in progress that will enable the type of set embodying an upstream-bulb generator driven through a speed-increasing

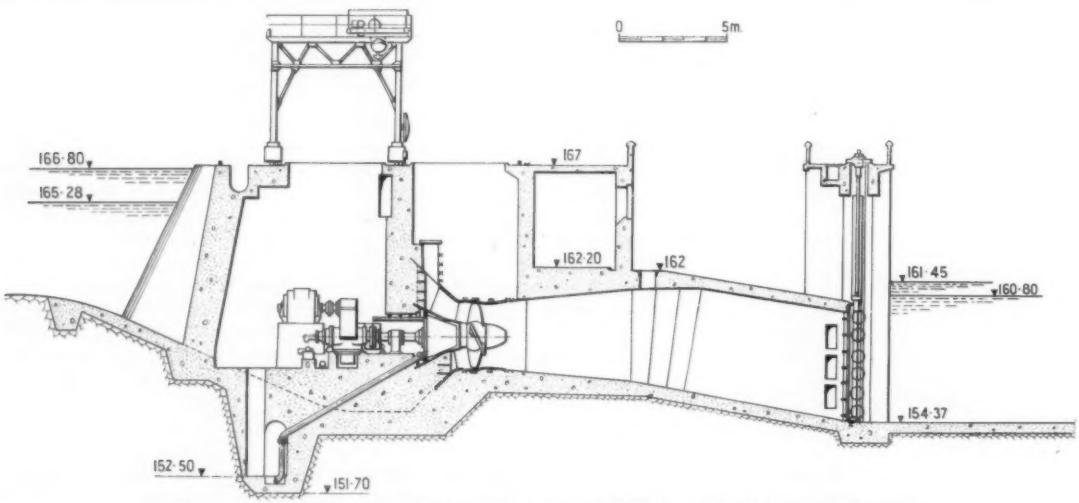


Fig. 1. Typical layout of pit-type axial installation (Wadrinau, 2,020 h.p.)

* Chief Engineer, Turbine Department, Ets. Neyrpic, Grenoble.

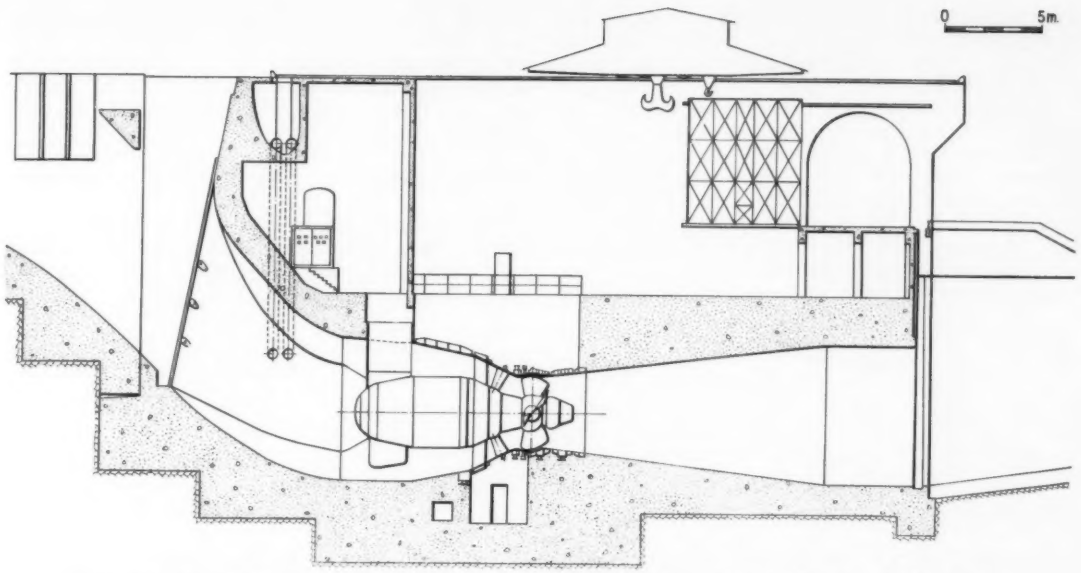


Fig. 2. General layout of bulb-type axial installation (Beaumont-Monteux, 12,000 h.p.)

gear to be perfected, but it seems that the capacity of such a set will be limited to about 20,000 h.p. Higher powers thus remain within the province of direct-coupled axial sets.

In addition to the limitations imposed by frequency regulation, other technical requirements also influence the design of bulb-type sets. Operating considerations such as the need for accessibility of vital components, ease of maintenance, etc., can lead to a substantial increase in the cost of an installation, particularly one of moderate capacity. Only operating experience with these machines has been able to show to what sizes it is reasonable to press the "monobloc" idea, which in the first instance was applied more particularly to low-power machines. The monobloc conception can now be seen to be applicable to installations comprising a fairly large number of sets the runners of which do not exceed 3–3·5 m in diameter. In the case of stations equipped with a few sets of medium power, where factors of interchange-

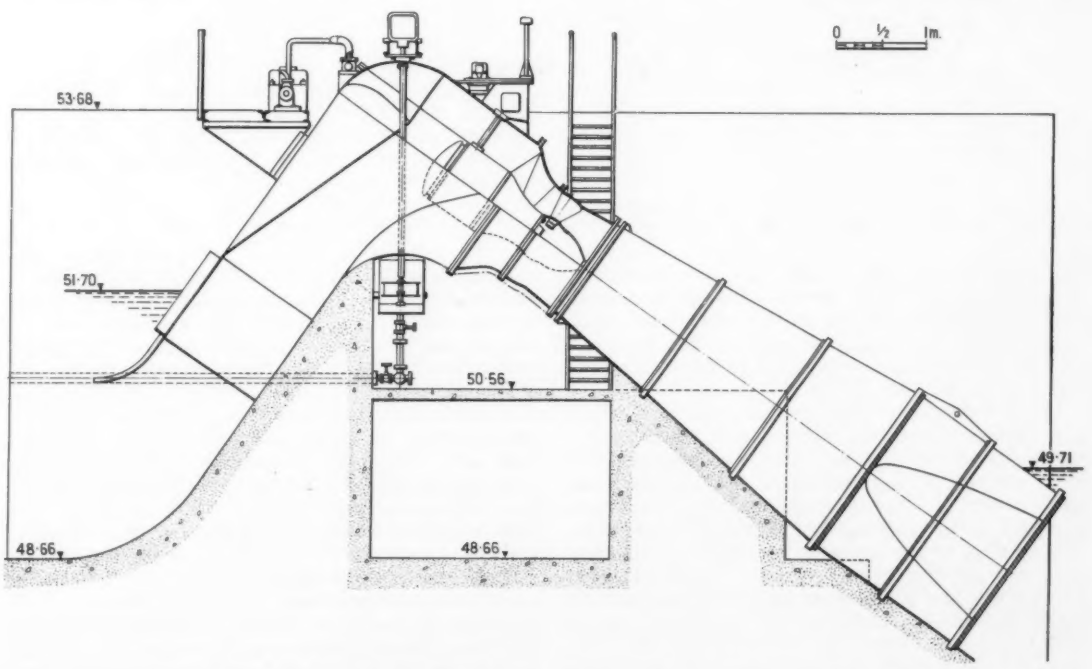


Fig. 3. Syphon installation for micro bulb-type set (La Maignannerie, 69 h.p.)

ability and standardisation are of less interest, the use of machines embodying a speed-increasing gear enables the problems of accessibility and maintenance to be resolved easily.

For large axial sets only operating experience with machines of adequate size will enable their constructional limits to be determined. The machines at Argentat (16,000 kW, 8–16·5 m head), Beaumont-Monteux (8,800 kW, 9·85–12·48 m head), and Cambeyrac (5,000 kW, 10·75 m head), which have given complete satisfaction since they were placed in service, and the St. Malo machine (9,000 kW, 5·5 m head) installed last year, show that the technique of building bulb-type sets is now fully developed. Further, these plants enable the practical limits of large machines suitable for powerful installations to be defined. It is now possible to envisage the design of the forthcoming huge tidal-power plants with a high degree of certainty.

The downstream-bulb set is also of interest where large powers are required. In point of fact it was towards this solution that we were drawn to begin with when studying tidal power. At that time, when turbine runners of large diameter equipped with movable blades were envisaged, it seemed that the problems relating to the connections between the rotating parts and the control of the blades would be easier to resolve with a downstream bulb. It is now possible to contemplate the construction of large downstream-bulb units. With this type of machine the alternator may be located either in the upstream or the downstream bulb, and it is even possible to use two alternators, one on either side of the runner. This arrangement, indeed, considerably increases the specific output of this type of machine, for the capacity is limited only by that of the alternator that can be accommodated within the dimensions imposed by the hydraulic circuit.

SMALL-CAPACITY AXIAL UNITS—"MICRO" SETS

First of all we will enunciate the three basic principles we have adopted to define small-capacity axial units, and then we will pass under review the principal types of machine actually installed.

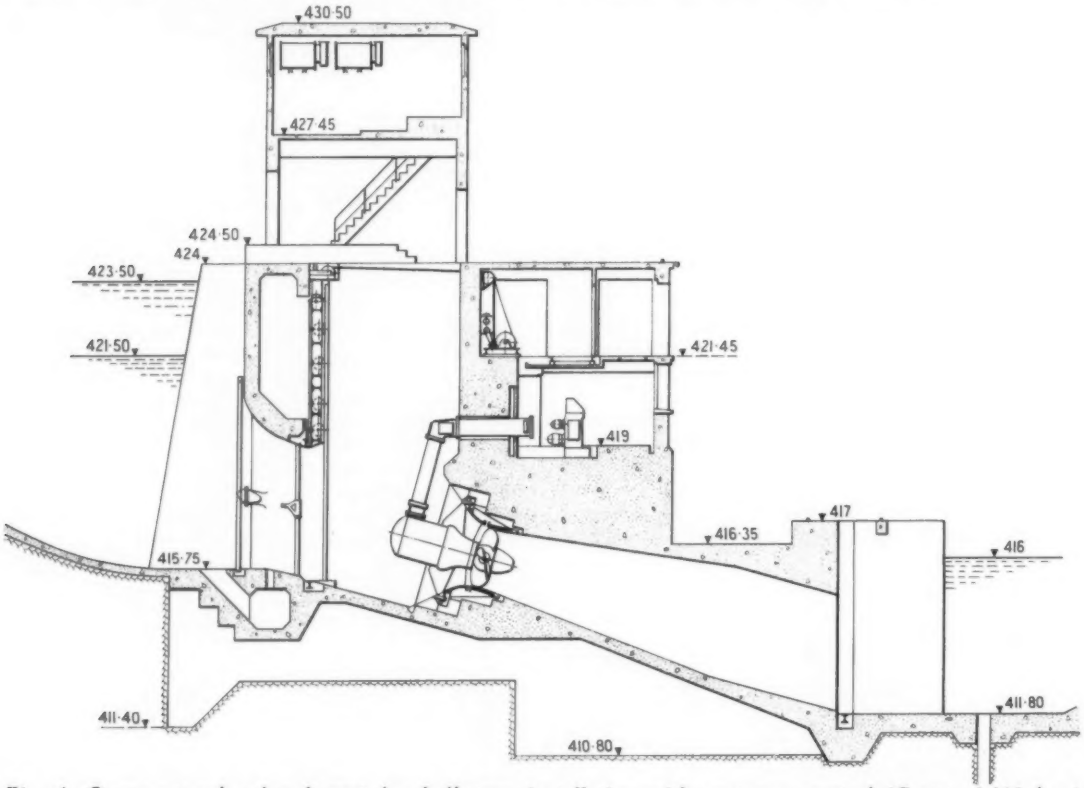


Fig. 4. Open-water-chamber layout for bulb-type installation with upstream control (Castet, 1,100 h.p.)

Standardisation. In the manufacture of small machines, purpose-built construction is obviously a serious economic handicap, and standardisation is the only way of obtaining economic production. Series production is conducive to accuracy and interchangeability of parts.

Simplification. Simplicity is one of the fundamental characteristics of axial sets. Even the first machines built were simple by comparison with conventional units, but in the light of experience it is possible and desirable to proceed further in this direction. If possible the turbines have fixed-blade helical runners, and the generators are of the induction type.

Replaceability. In case of a mishap the faulty machine can be replaced by a complete new set. This system is favourable to operation because it reduces idle time to a minimum; it is also reasonable because such an installation usually comprises a large number of identical sets distributed over one or several dams,

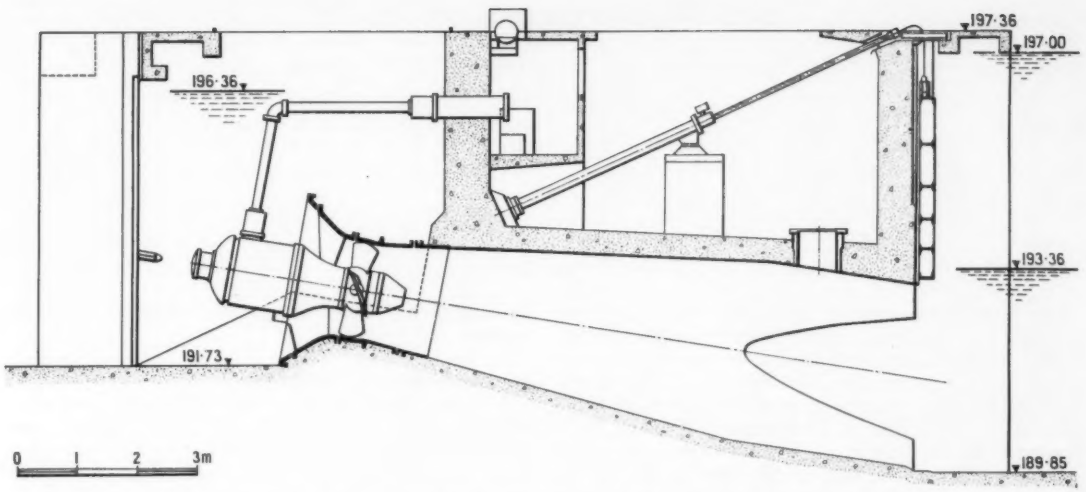


Fig. 5. Open-water-chamber layout for bulb set with downstream control (Verdun, 327 h.p.)

and thus the capacity of one set is small in comparison with that of the whole installation.

Pit-Type Sets

There are two types of low-capacity axial sets—the pit type and the bulb type.

The pit type is that which departs least in layout from conventional machines. On the upstream (or occasionally downstream) side of a horizontal or near-horizontal turbine (see Fig. 1) is a watertight pit housing an alternator driven either direct or through a speed-increasing gear. This arrangement does not constitute any radical departure from the conventional horizontal layout. Nevertheless, the Wadrinau station (France) shows, as one would expect, that the civil engineering is greatly reduced and constitutes the prime factor in the reduction of cost. The achievement of a reasonable efficiency, however, depends on the satisfactory production of the somewhat complex hydraulic shapes that must be adopted.

If necessary, the inertia of the set can be increased by installing a flywheel near the alternator in order to facilitate regulation and to enable the alternator, if synchronous, to supply an independent system.

Bulb-Type Sets

If an attempt is made to carry the process of simplification further, we arrive at the bulb-type set (Fig. 2). The alternator is in one unit with the turbine, and its rotor can revolve in air, oil or compressed gas. Whatever the medium the circulation of the fluid carries the heat to be dissipated to the walls of the unit. As in the pit-type machine, the alternator can be driven through a speed-increasing gear.

Three types of layout are in use for bulb-type machines. In the first, used for micro sets, the machine is mounted in a syphon. Fig. 3 shows such a set, which has a runner 1,120 mm in diameter. Starting is effected by exhausting the air from the syphon by means of a vacuum pump—an operation that is effected in less than a minute—and the opening of an air valve stops the machine in a few seconds. The generator is of the induction type and has a smooth-faced squirrel-cage rotor running in oil under pressure. The turbine runner is of the screw type with fixed blades, for these machines operate either at full capacity or not at all. When the upstream level descends below a predetermined minimum (often imposed by navigation) an automatic device opens the air valve and stops the machine; the machine is automatically started again when the level rises to a specified value.

In the second type of layout the set is located in an open water chamber controlled by an upstream gate. A 1,100 h.p. installation of this kind is depicted in Fig. 4. The wide variations in discharge necessitate the use of movable blades. The generator is similar to that in the preceding example. Starting is effected by using the generator as an induction motor, the gate being opened and the runner blades closed. After the speed has been brought up to the region of synchronism the machine is placed under load by opening the blades by means of a load regulator, which can be remote controlled.

In the third type of layout an open water chamber is also used, but the closure is on the downstream side. Fig. 5 shows an installation with a safety gate placed at the end of the draft tube. This arrangement often enables the upstream-downstream length of the installation to be reduced. In the station illustrated the blades are closed automatically by a spring as soon as the set is disconnected from the system. Control of the blades is effected by a mechanism housed in the bulb, the only part external to the set being the oil pump. Loading of the machine is electrically remote controlled.

Bulb-Type Generators

The squirrel-cage induction-type generators used for these installations are very robust and require the minimum of maintenance as they need neither slip-rings nor brushes subject to wear. Together with the turbines to which they are directly coupled they form a monobloc assembly immersed in the water stream. They are filled with oil, which has the following functions: (a) first and foremost, to transfer the heat produced to the walls of the bulb and thence to the water, (b) to insulate the stator winding, (c) to lubricate the two bearings and the thrust block, (d) to prevent water from entering the bulb; for this reason the

TABLE I.—BULB AND RUNNER DIAMETERS (mm)

Bulb	1,700	1,400	1,140	875
Runner 47	2,500 2,240	2,000 1,800	1,600 1,400	1,250 1,120
Runner 88	2,500	2,240 2,000	1,800 1,600	1,400 1,250 1,120

oil is maintained under a slight pressure by a conservator tank connected to the bulb by simple piping.

The frame consists of a steel plate bent into a ring, which is in contact with the water and also forms part of the magnetic circuit, enabling a large proportion of the iron losses to be dissipated directly. Sealing between this ring and the upstream cap on the one side and the inlet ring on the other is effected by special rubber jointing inserted in a groove in each flange.

The stator winding usually consists of only one or two conductors per slot in order to ensure robustness and long life.

In the case of sets with movable blades, the hub of the generator rotor forms the cylinder of the runner servomotor.

It should be noted that because these generators are of the induction type they cannot supply an independent system, but that the system must be simultaneously fed from synchronous machines, which fix the frequency and supply the necessary reactive power.

Standardisation of Bulb-Type Units

For the reasons given above it has been necessary to standardise bulb-type units, but to begin with, this standardisation has been studied only for induction-type sets running in oil. This study has resulted in the preparation of a "grid" (see Figs. 6 and 7), similar to those used in the manufacture of pumps, which enable the machine corresponding to any given characteristics to be chosen. On these grids will be found a series of little curved-sided polygons representing the zone of optimum performance of each machine. The five sides of each polygon are defined as follows: The upper slightly inclined side is the line of maximum inclination of the runner blades; the two sides on the left are fixed by hydraulic considerations (maintenance of efficiency at an acceptable value); the right-hand side is the line of maximum

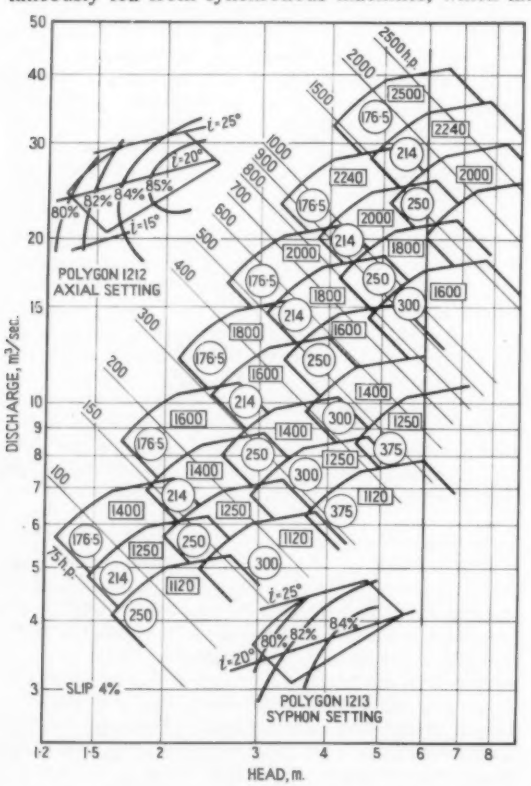


Fig. 6. Grid for runner applicable to heads of up to 6 m

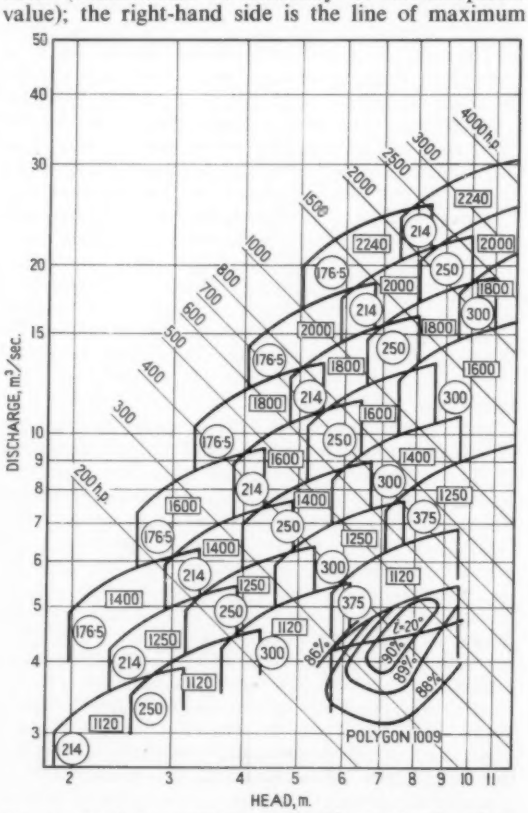


Fig. 7. Grid for runner applicable to heads of up to 11 m

TABLE II.—SOME UPSTREAM-BULB-TYPE INSTALLATIONS

Installation	No. of sets	Type of blades*	Unit capacity	Head	Speed	Runner diameter
			h.p.	m	r.p.m.	mm
Castet	2	M	1,100	7·00	250	1,650
Mercues I	1	M	386	3·50	176·5	1,650
L'Ame	1	F	200	1·90	158	1,600
La Maignannerie	1	F	69	1·85	214	1,120
Lagarde	4	F	252	2·25	176·5	1,600
Verdun	2	M	327	3·13	176·5	1,650
La Caillade	4	F	209	3·50	250	1,120
Mercues II	2	F	430	2·90	250	1,400
Capdenac	3	F	1,020	6·00	250	1,800
Marcillac	4	F	165	3·00	257	1,120
Ramier	2	F	510	4·25	300	1,400
Esch-sur-Sure	2	M	392	2·80	176·5	1,800
(Luxembourg) II	2	M	353	2·55	176·5	1,800
III	2	M	425	3·00	176·5	1,800
IV		M	312	3·00	214	1,400

* F = fixed blades
M = movable blades

power of the runner; the lower side is located to provide a sufficient overlap with respect to adjacent polygons.

Thus each polygon defines the possibilities of each turbine at the corresponding head for a given speed of rotation and runner diameter. Thus, by the judicious juxtaposition of these little polygons on the general head/discharge diagram it is possible, with the minimum number of turbines and of speeds of rotation, to cater for every case of a low-head installation utilising discharges between 3 and 30 m^3/sec and heads below 11 m.

Actually the wide variation in head between 1·50 and 11 m cannot be covered rationally with a single wheel profile, and it has been thought preferable to prepare two grids, one for a runner (4M88) having a high specific discharge but introducing a risk of cavitation under heads above 6 m, and the other (4M47) having a smaller specific discharge but making possible a normal installation for heads up to 11 m by reason of its immunity to cavitation. These two grids have been devised to reduce to the utmost the number of runners on the one hand and the number of bulbs on the other—one bulb diameter corresponding to several wheel diameters independently of the type of blade. Table I shows that this reduction is important and has enabled four bulbs to cover all requirements. This reduction in the number of bulbs has enabled us radically to reduce the number of types of generator as compared with the number originally envisaged. For each diameter of bulb the generator must correspond to standard speeds and must adapt itself perfectly to the limits of power imposed by the turbine, these requirements being met by a choice of three or four lengths of iron core.

The interrelationship between hydraulic and electrical design should now be abundantly clear, and it has been necessary to go to considerable lengths to harmonise to the best advantage considerations that in many cases were contradictory.

Development of Construction

Since the first bulb-type machines were built, the development of construction has been directed specifically towards simplification, as we have had occasion to indicate above. This simplification has resulted particularly in the following:

(1) The omission of the vanes guiding the oil along the cooling surfaces; experience has shown these to be unnecessary.

(2) The omission of the oil pump originally installed to circulate the oil for cooling purposes.

(3) The omission of most of the temperature-measuring devices.

(4) The simplification of the blade-operating gear in Kaplan machines.

In movable-blade machines the oil in the runner hub does not mix with that in the generator, but in the near future we shall probably be able to use the same oil if all possibility of the entry of water can be eliminated.

Table II gives a list of some standardised upstream-bulb-type installations.

(To be continued)

New Factory Opened by Sandvik. A new factory for the production of rock-drilling equipment was recently opened in Stockholm by the Sandvik Steel Works Co. Ltd., of Sandviken, Sweden. It will mainly produce detachable bits and extension steels for drilling holes of more than 1½-in diameter. The factory has been equipped with up-to-date machine tools, some of unusual design. Another feature of the new premises is a hardening department planned specifically for drill-steel manufacture.

The biggest detachable bits to be made will be 9 in in diameter. Each of these weighs 132 lb including the tungsten-carbide insert, which itself weighs 17½ lb. One of the smallest Sandvik products planned for production will be a plug-hole drill steel, 0·3 in in diameter and weighing only a few ounces. All the Sandvik hard metal required for the bits will be manufactured at the company's Stockholm factory. This hard metal, which is inserted into the tip of the drill steel by a largely secret process, is a sintered product consisting of approximately 90% tungsten carbide, 10% cobalt and small proportions of other materials.

NCK-Rapier Limited. This firm have sent us two catalogues, one of which gives full particulars of their crawler cranes which will handle loads of up to 62 tons, and the other is descriptive of the 545 Sprawler which lifts up to 40 tons with outriggers.

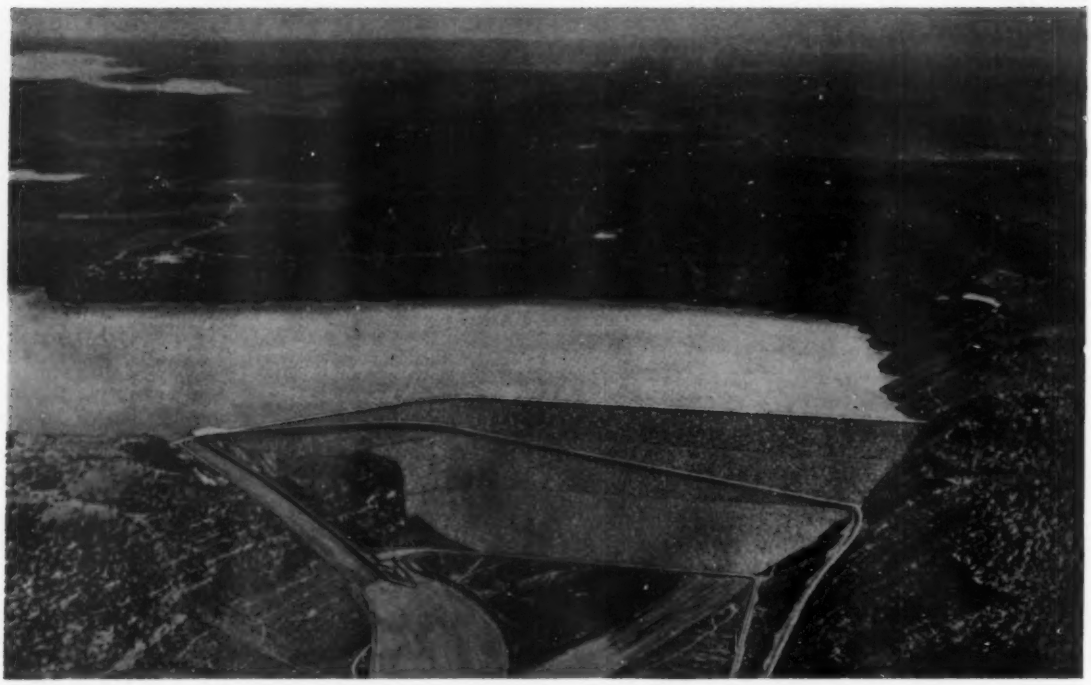


Fig. 8. Artist's impression of Navajo dam

The Upper Colorado River Project

This series of articles describes the constructional work on the Glen Canyon, Navajo and Flaming Gorge dams. The present article is devoted to Navajo dam

By IAN B. MACKINTOSH, M.A., A.M.I.C.E., M.ASCE.*

PART TWO

A NEW earthfill dam (Fig. 8), which will be one of America's highest, is being built at record speed in the deep curving canyon of the San Juan River in north-western New Mexico, by a joint venture of Morrison-Knudsen Co. (sponsor), Henry J. Kaiser Co., and F & S Construction Co. as a unit in the US Bureau of Reclamation's Upper Colorado River project. The structure is Navajo dam, named after the proud Indian people who have made this wind-worn region of sandstone mesas and sagebrush their tribal homeland for centuries. It reaches 405 ft in maximum height and requires about 26 million cu yards of rolled fill. A reservoir will be formed 34 miles long with a usable storage capacity of one million acre ft, which will enable the river's widely fluctuating flow to be regulated, thus aiding sedimentation control and providing precious irrigation waters for some 115,000 acres of land on the nearby Navajo Indian reservation. The $23 million contract for the dam is expected to take only 3½ years to complete compared with 4¾ years called for in the contract.

* Senior Engineer, Taylor Woodrow Construction Limited, London.

Geology

Rising in the San Juan Mountains of Colorado, the San Juan River flows southward through mountainous terrain into the high plateau country of north-western New Mexico. Rocks in the reservoir basin belong to the Wasatch formation of Eocene age. These rocks are undisturbed by faulting and are impervious to the extent that the San Juan River itself forms the drainage for ground water as well as for surface water.

Just above the dam site the San Juan River flows in a southerly direction, but at the upstream toe of the dam it makes a sharp hairpin turn and flows nearly north for about 1,000 ft before continuing on to the west. A narrow sandstone point projecting out from the right side serves as the right abutment, and the left abutment is a steep slope which continues around a long sweeping curve.

The rock at the site belongs to the Wasatch for-

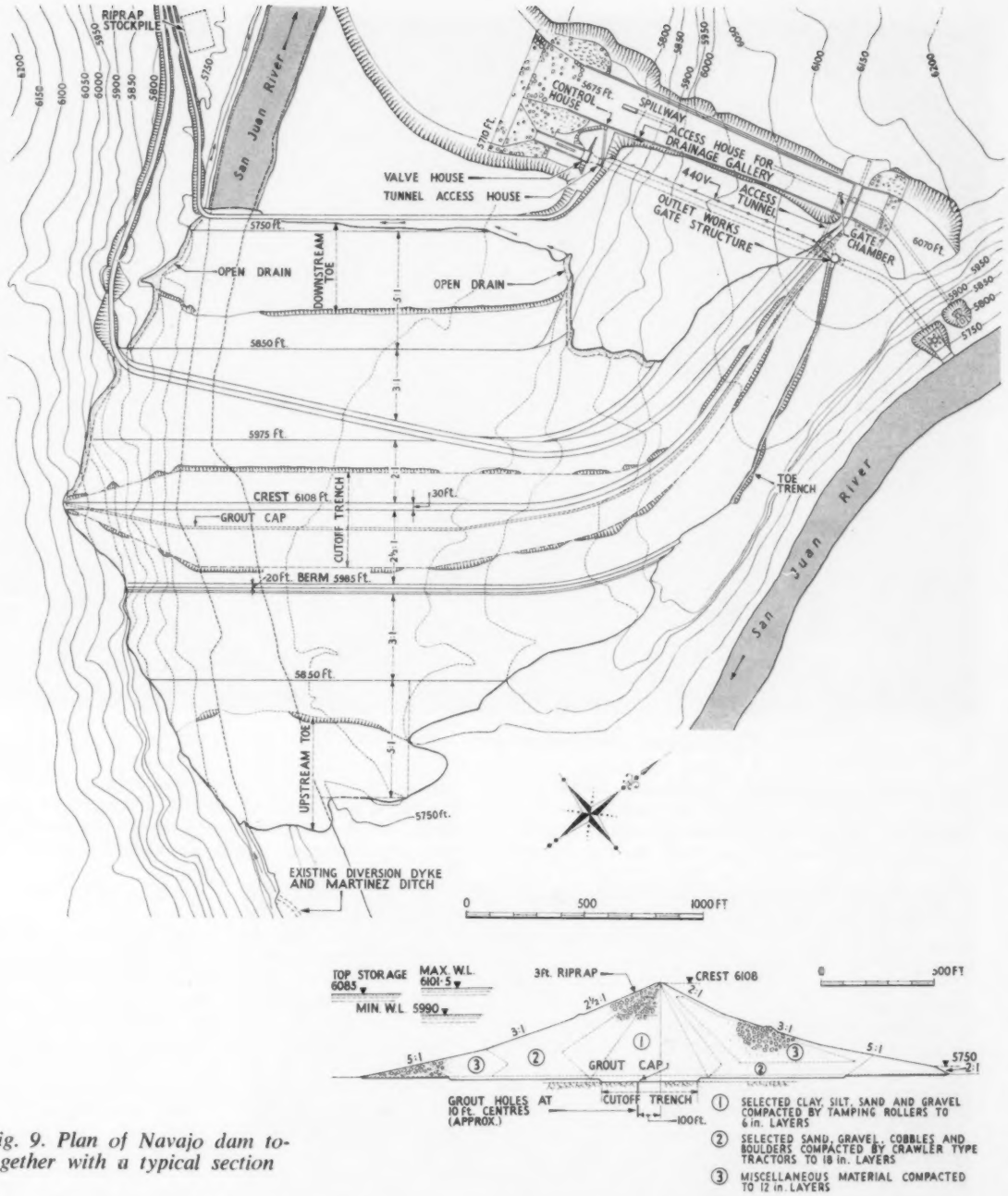


Fig. 9. Plan of Navajo dam together with a typical section

mation, consisting principally of sandstone with minor beds of shale. It is massive with many beds up to 50 ft thick, and is moderately well cemented in the more-resistant beds although other layers crush easily. Shaly beds predominate near the river surface and are usually from 2 to 10 ft thick and separated by equally thick beds of sandstone. The strata are not continuous for far, shales grading into sandstones abruptly and vice versa, a typical feature of continental deposits like the Wasatch formation.

Generally the sandstone is finer grained and more completely cemented in the lower half of the abutments. Near the spillway there is some coarse-grained sandstone, which is porous and friable enough to be crushed in the fingers, but these beds are localised in a small area near the top of the abutment. The rock is fairly free from joints except near the surface on steep slopes, where the hillside creep—due to softening and settlement in the shale beds—leaves vertical fractures in the sandstone. The left abutment contains more open fractures than the right because it is steeper and contains more shale. Below river level the rock is mostly watertight but a few beds will "sweat" due to lack of complete cementation in the

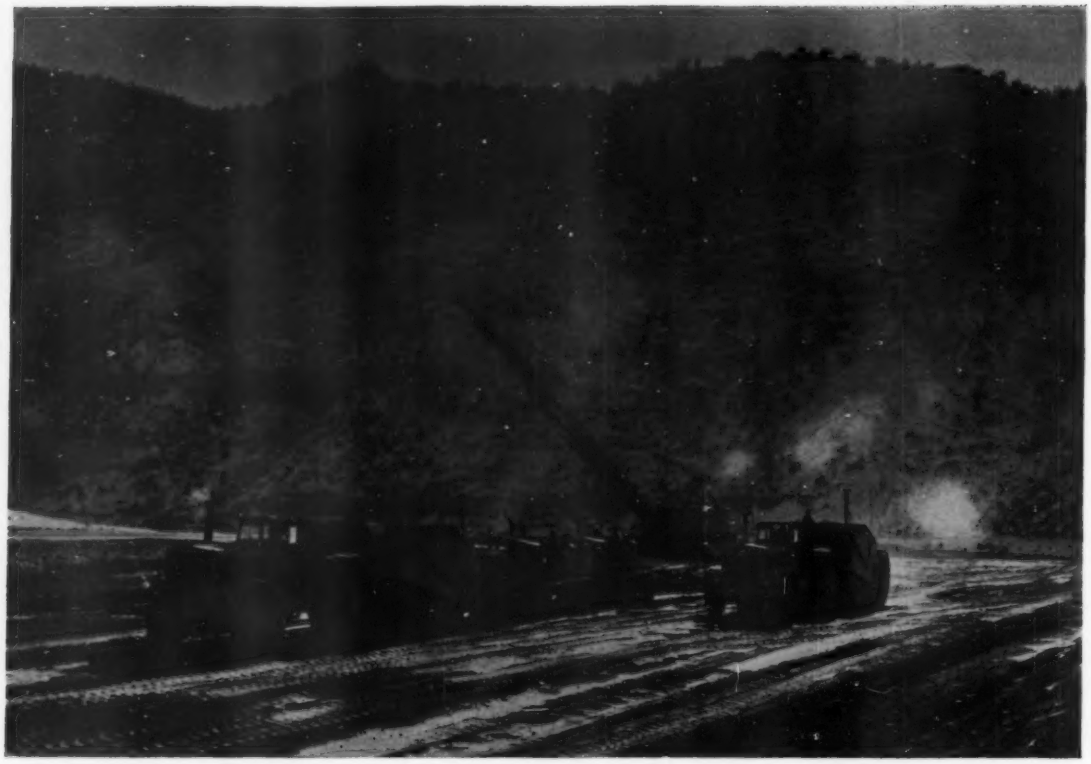


Fig. 10. Two push tractors assisting twin-engined 24-cu-yard scraper

more coarse-grained beds. Geological conditions in the stream channel and along the cut-off line are exceptionally favourable. Bedrock averages about 12 ft below the river bed and lies relatively flat, changing only 5 ft in elevation in a 700 ft length of cut-off trench. About 10 to 12 ft of clean, well-graded, well-rounded gravel and cobbles cover the shale and sandstone bedrock and this is overlain by silty sand which ranges up to 25 ft in thickness.

Dam Design

The dam embankment, designed as a three-zone structure, will have a maximum base width of 2,300 ft and a crest width of 30 ft at elevation 6,108 ft, and the length at crest will be 3,800 ft (Fig. 9). Zone 1, or the impervious portion of the embankment, will consist of a mixture of selected clay, silt, sand, and gravel, compacted by sheepsfoot rollers in 6 in layers. Zone 2 will consist of selected sand, gravel, and cobbles, compacted by crawler-type tractors or vibratory rollers in 18 in layers. Zone 3 will consist of a mixture of selected clay, silt, sand, and gravel, compacted by sheepsfoot rollers in 12 in layers. The upstream slope of the embankment above elevation 5,985 ft will be protected against wave action by covering it with heavy riprap.

Toe foundation stripping at the upstream and downstream limits of embankment, as shown on the maximum section in Fig. 9, consists of the removal of humus and top soil. Under the Zone 2 portions of the embankment all materials are removed down to the stable sand, gravel, and cobble deposits. All materials above bedrock are removed from beneath the Zone 1 section of the embankment. This area is considered as the cut-off trench, and a single grout curtain 260 ft deep extending between abutments ensures watertightness in the foundation beneath the fill.

Instrument Installations

The embankment test apparatus to be used for studying the behaviour of the dam during construction and during its life comprises piezometers for observing pore fluid pressures in the foundation and in the embankment, horizontal and vertical movement instruments to provide a measurement of internal vertical and horizontal movement of the embankment, and surface-settlement points for observing cumulative settlement and deflection on the completed surface of the embankment.

The piezometer construction consists of 12 foundation-type and 40 embankment-type instruments located in the maximum section of the dam. Two water-filled plastic tubes will lead from each piezometer up to bourdon-tube compound altitude gauges, installed in a reinforced-concrete terminal well in the downstream toe of the embankment, to which pore pressures will be transmitted.

Borrow Areas

Extensive borrow-area explorations in the near vicinity of the dam site were carried out to locate the 26 million cu yards of material required for embankment construction. Suitable materials were located in 16 borrow areas, all within two miles hauling distance of the dam. For tendering purposes these areas were

divided into five groups by relative elevation and location as far as was practicable.

Borrow excavation, after stripping, is essentially a two- or three-cut operation. The top cut recovers impervious materials for Zone 1 of the embankment, below which the pits yield relatively clean sand-gravel and cobbles for use in Zone 2. A mixture of the two materials around the contact line provides the Zone-3 portion. Thus the zoning scheme for the embankment is designed to make maximum use of the borrow areas. Explorations disclosed similar soil profiles in all borrow pits regardless of location and elevation with respect to the stream bed. Valley floor pits and those 300 and 700 ft higher all have the same characteristics.

For proper moisture conditioning of Zone 1 and Zone 3 materials, irrigation of borrow pits is required before excavation. The construction specifications require that the moisture be introduced at least 30 days in advance of excavation to ensure uniformity of distribution. The contractor has used various methods in performing this operation but shows preference for sprinkler irrigation and check area flooding. Experience has shown the need for irrigating 60 to 90 days ahead of excavation, so the moisture conditioning programme has had to be considerably advanced. There is no requirement for preconditioning of Zone-2 materials except for any drainage required.

Excellent concrete aggregates are obtained from the sand-gravel and cobble deposits. Hard basaltic rock for riprap will be obtained from quarries located some 60 miles east of the dam.

Earthmoving Equipment

The Zone 1 material is being moved by a new type of rubber-tyred carrying scraper, the Euclid TS 24 (Fig. 10), which has a four-wheel tractor with a 365 h.p. turbo-charged engine and also a second engine of 220 h.p. mounted at the rear of the scraper to give more power on uphill grades. The earlier form of this scraper had two wheels only at the front end, but although this is an advantage in getting traction in mud, it prevents the scraper from riding as smoothly as with a four-wheel tractor and so gives a higher maintenance cost than the new form. These scrapers with 18-in side-boards carry 24 cu yards, which is somewhat less than their nominal capacity, and when loaded can travel at 40 m.p.h. on the level and at 8 to 10 m.p.h. up a 6% grade. They are loaded in 20–25 sec by a pusher team of two Euclid TC 12 twin tractors (416 h.p. each) with the rear engine of the scraper idling to avoid jack-knifing the rig. There are 11 scrapers on the job but the actual number used depends upon the length of the haul. Normally three pushers operate in the borrow area, and when one pusher only is being used the scraper works its rear engine during loading.

Walking Dragline

The material for the pervious Zone 2 is being dug by a 17-cu-yard Monighan 450 W walking dragline with a 125 ft boom (Fig. 11), which fills a mobile 60-cu-yard hopper beneath which 30-cu-yard bottom-dump Euclid trucks are loaded. The most favourable loading situation is when the Monighan is working a cut of a depth about equal to the height of the loading hopper. In that case, after the dragline bucket has been filled the machine does not have to spend valuable time hoisting the bucket up to the level of the top of the hopper, which is 28 ft high. But this situation cannot often be obtained and a cut of 16 ft in depth is more usual. The output of the machine can vary from 800 cu yards per hour for an unfavourable loading situation, to 1,300 cu yards per hour for the most favourable one. The Monighan, which costs $1 million when new, has an 850 h.p. Cooper Bessemer diesel engine. This particular machine was brought to Navajo dam from the St. Lawrence Seaway.

Twelve bottom-dump 30-cu-yard Euclid trucks are used to haul the material from the loading hopper filled by the Monighan. The hopper has two hydraulically operated gates—a sliding type for wet material and a chute-type drop gate for dry material. A 75 h.p. generator supplies power to the hydraulic pumps, and there are air jets in the hopper to keep the material loose. The gates are controlled by an operator and the trucks are loaded in 8 to 10 sec. Each of the four legs of the hopper is mounted on a pair of Athey tracks, which can be rotated to move the rig in any direction; the hopper is towed by crawler tractors when being moved. The Euclid trucks can reach a speed of only 4 m.p.h. up the 6% grade on

Fig. 11. Monighan dragline with 17-cu-yard bucket dumping into 65-cu-yard crawler-mounted hopper

Fig. 12. Drilling jumbo in 20 ft diversion tunnel in sandstone and shale

the haul roads, and so the twin scrapers, which can make 8 to 10 m.p.h. uphill, have to pass the trucks when they are using the same haul roads.

Starting in September 1958 9 million cu yards out of the total of 26 million cu yards of fill had been placed by February 1960. A placing rate of 600,000 cu yards per month has been achieved and it is expected, after the river has been diverted, to reach 1 million cu yards per month. The dam embankment is expected to be completed in December 1961.

Compaction Equipment

The impervious material is spread as it is dumped by the scrapers. A tractor-drawn disc harrow and land plane are then used to ensure complete processing and levelling, prior to final compaction in layers of 6 in or less by rolling. A self-propelled sheepsfoot roller designed by the contractor's staff is being used. It has four drums each 5 ft 6 in in diameter and 6 ft long, and each drum is driven by a 71 h.p. G.M.C. diesel engine. These are manifolded to be operated on a single throttle. The drums do not need loading and the whole rig weighs 55 tons. A standard roller is required by specifications to make 12 passes, but since the self-propelled unit is a double roller only six passes are required when it is used.

For the gravels that form the pervious zones of the dam, compaction is obtained with three solid-steel vibratory rollers assembled in a V formation for hauling by a single tractor. The contractor has been given permission to use vibratory rollers for compaction in place of a 20-ton crawler tractor.

Soils Testing

The impervious material should have a wet density of 133 lb per cu yard when compacted. The borrow areas are brought to near optimum moisture content by means of sprinklers. The borrow material is checked for moisture content by drilling and taking cores. A sample of material for testing in the laboratory is taken from every 2,000 cu yards of finished embankment in Zone 1 and every 10,000 cu yards in Zone 2.

Sequence of Work

The general procedure has been to take all the upstream material first and build up the right-hand side of the embankment prior to river diversion. Because the placement of fill got ahead of the diversion works, permission was given to start building up in September 1959 on a second terrace nearer the river. At that time 6 million cu yards of fill had been placed and the embankment had reached elevation 5,910 ft to withstand the 1960 flood expected around April 1. Diversion was made on January 4, 1960, and an embankment consisting of the upstream half only of the final cross section was then pushed over the river to the left abutment, the equipment then concentrating flat out in this area to raise its height to an elevation of 5,910 ft before April 1. After diversion, three eight-hour shifts are being employed working for 7 days in place of the two nine-hour shifts working 5 days used prior to that time. A saving of 45 days in the programme was achieved by getting the grout cap in the river bed completed in advance of diversion by working in a series of cofferdams.

The river will initially pass though the auxiliary outlet works which consist of an intake, a 7 ft diameter concrete-lined tunnel and a gate chamber, these works being located at an elevation of 5,771 ft. This compares with elevation 5,882 ft for the main 18 ft 9 in outlet tunnel. Both tunnels, without gates, will be used for diversion until the dam embankment reaches sufficient height to permit safe storage of water. Gates will then be installed, first in the auxiliary outlet tunnel and then in the main outlet tunnel, in a sequence that will permit the simultaneous accumulation of storage and continuous downstream release of water as was previously mentioned. It is expected that the rate of discharge from Navajo dam after ultimate development of the Navajo irrigation project will be compensation water up to 600 cusecs.

Outlet Works

The main outlet tunnel for controlling release of water from the dam is 1,600 ft long and has a finished diameter of 18 ft 9 in with a design thickness of concrete of 22 in. The excavation plant used for driving the tunnel comprised an Eimco 105 loader on crawler tracks loading into Koering 6-cu-yard rubber-tyred diesel dumpers. Temporary supports in the tunnel consist of steel arch ribs 6 × 6 in WF at 10 ft centres (Fig. 12). The concrete lining of the tunnel is being pumped into 48 ft long Blaw-Knox steel travelling forms in two operations, the invert of the circular section being placed first and the arch later. Three or four lengths are achieved in a six-day week of three shifts per day; the gangs are not specialised on one operation but do whatever is required. The form may be stripped 17 hours after the end of placing the concrete, and a curing compound, Protex, is then sprayed on to the surface of the concrete.

At the upstream end of the tunnel there will be a concrete tower intake structure and part way along at the axis of the dam a gate shaft in which to house a 6 ft × 13 ft fixed-wheel gate. Downstream of the gate shaft the tunnel will have a 110-in diameter steel pipe which bifurcates at the outlet into two 72-in ring follower gates and two 72-in hollow-jet valves. The steel lining is to allow for possible future provision of a generator at the dam. The gate shaft is 365 ft deep and was excavated by first sinking a 36 in diameter calyx hole and then mucking out the subsequent enlargement by working downwards and removing the material from the tunnel below after it has fallen down the calyx hole. In the tunnel lining between the gateshaft and the intake structure are embedded a 1½-in diameter pipe for the delivery of hot air to the intake for de-icing and also a 1¼-in copper pipe inside a 2-in diameter steel tube which will connect to a reservoir-level recording gauge at the gate house.

Flood flows occur mostly due to snow-melt in the spring or early summer and seasonal rains in the autumn. The spillway consists of a concrete crested structure without gates located on the right abutment, a spillway chute 139 ft wide constructed on the hillside, and a 195 ft wide stilling basin (Fig. 13). The normal river flow ranges from 300 to 3,000 cusecs. The worst flood on record was 24,000 cusecs and the spillway has a design capacity of 34,000 cusecs at maximum water-surface elevation which is 6½ ft below the crest elevation of the dam. The reservoir has an area of 15,610 acres at normal high water. The surcharge storage available between spillway-crest elevation and maximum-water-surface elevation is 276,000 acre ft.

Fig. 13. Excavating the stilling basin. Note the high scalers seen inside the circle

Concrete Plant

The total volume of concrete in the works is 72,000 cu yards. The aggregate processing plant has a design capacity of 200 tons per hour, which is much in excess of that required for such a small quantity of concrete, but it will be operated for two nine-hour shifts per day to stockpile in a few months the aggregates required for the remainder of the contract. There is a surplus of ⅜ in to No. 4 size material and this is wasted. The aggregate plant is located near the stilling basin alongside the batching plant, which has two 2-cu-yard Smith mixers.

Acknowledgments

The author's thanks are due to Mr. J. B. Bonny, President of Morrison-Knudsen Company, and to Mr. H. D. Gard, Project Manager for Morrison-Kaiser–F & S for their kind co-operation during his visit to the project. His thanks are also extended to *The Em Kayan* for permission to reproduce the photographs in Figs. 1, 4, 5, and 6.

REFERENCES

"Navajo Dam," by W. W. Brenner and J. D. Seery, US Bureau of Reclamation, 1959.

"Big Rigs Push Navajo Dam Fill Far Ahead of Schedule," *Engineering News Record*, August 13, 1959.

(To be continued)

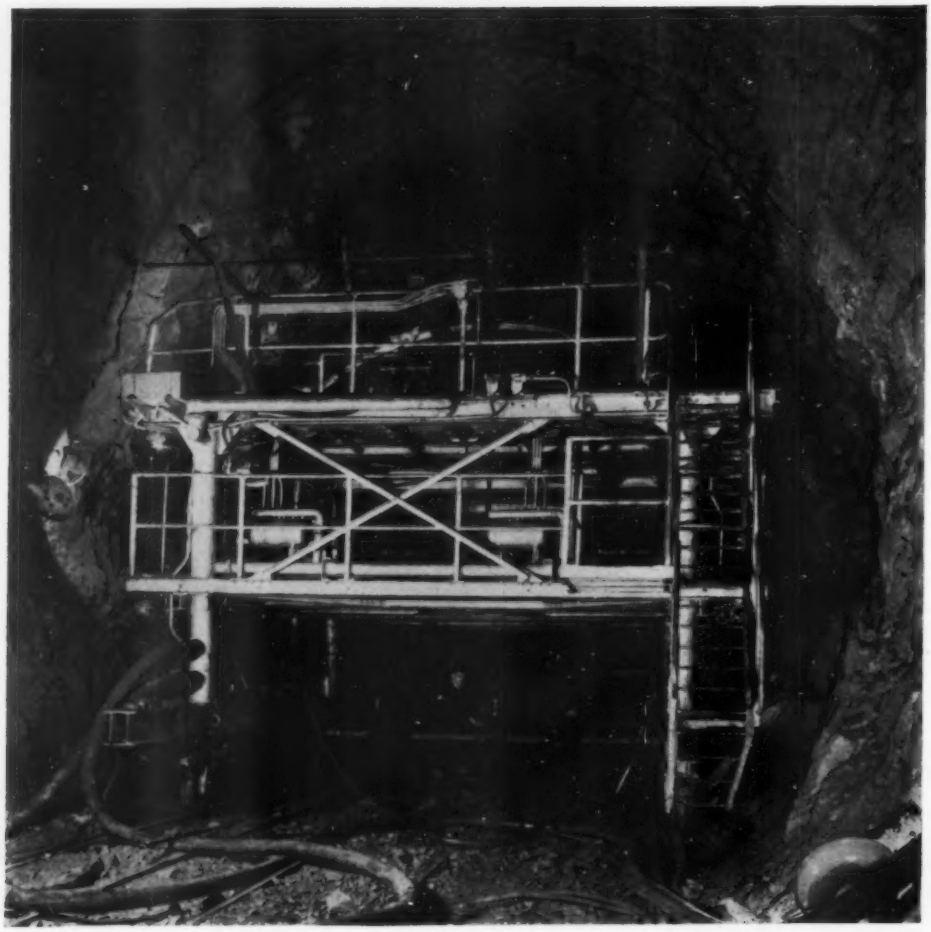


Fig. 1. The drilling platform in position at the Inverawe-tunnel face

Ladder Drilling Technique at Inverawe Tunnel

This article briefly outlines the Awe project in Argyllshire and describes the ladder drilling method employed in the Inverawe tunnel

THE Awe project of the North of Scotland Hydro-Electric Board is designed to utilise the catchment of the River Awe, supplemented by the collection of waters from the northern slopes of Ben Cruachan and the diversion of the Loch Nant catchment. The total catchment area involved is 324 sq miles. Fig. 2 is a general plan of the area, and also shows the proposed new works.

The project comprises three main sections, which are interdependent to a limited degree, and these sections are known as Cruachan, Inverawe and Nant. The Cruachan section consists of a pumped-storage scheme together with a system of aqueducts and tunnels to divert the headwaters of the Rivers Liever and Noe on the north side of Ben Cruachan. The diverted water will be delivered into the upper storage pond formed by a dam at the head of the Cruachan Burn, nearly 1,200 ft above Loch Awe. From this reservoir, water will be led by shafts to an underground power station inside the mountain and the water will be conveyed to and from Loch Awe by a tunnel below loch level. The purpose of this installation is to use the output from surplus generating capacity in Scotland at nights and week-ends to

pump water to the high-level reservoir, from which it can be released to generate electricity at peak-load periods. The combined plant will have an installed capacity of 400 MW.

On the Inverawe section, water will be drawn off from the River Awe upstream of a barrage, and passed through a three-mile-long tunnel beneath Ben Cruachan to a power station situated about half-a-mile upstream of the mouth of the river. A better site for the power station would have been near sea level on Loch Etive, but the river-bank site was favoured so that the outflow would attract salmon into the river. The power station, which will be a relatively low-head, run-of-river installation (although Loch Awe provides an appreciable amount of natural regulation), is to have an installed capacity of 25 MW, and is expected to produce an average annual output of some 100 million kWh.

The Nant section of the project involves the construction at Loch Nant of a dam, which will be 1,150 ft long and 80 ft high, a tunnel, and an underground power station near Inverinan, which will discharge the diverted Nant water into Loch Awe. There will also be some diversion of adjacent streams into the tunnel. The installed capacity of the Nant power station will be about 18 MW and the average annual output some 27 million kWh.

The Awe project was authorised in May, 1959, at an estimated cost of £24½ million, and is scheduled for completion in 1966. Contracts have been let for the Inverawe and Nant works, and for part of the Cruachan section, including a three-mile access road from the Pass of Brander up to the Cruachan dam site. The consulting engineers for the Inverawe and Cruachan sections of the project are James Williamson & Partners, of Glasgow, and for the Nant section, Babtie, Shaw and Morton, of Glasgow. The contractor for the Inverawe tunnel is George Wimpey & Co. Ltd., of London.

The Inverawe Tunnel

From the constructional point of view, considerable interest has been shown in the Inverawe tunnel, where a drilling technique—known as ladder drilling—that is new to British practice is being employed. The tunnel has an excavated horseshoe section of 25 ft equivalent diameter, and will be lined with concrete to a minimum thickness of 9 in. It is believed

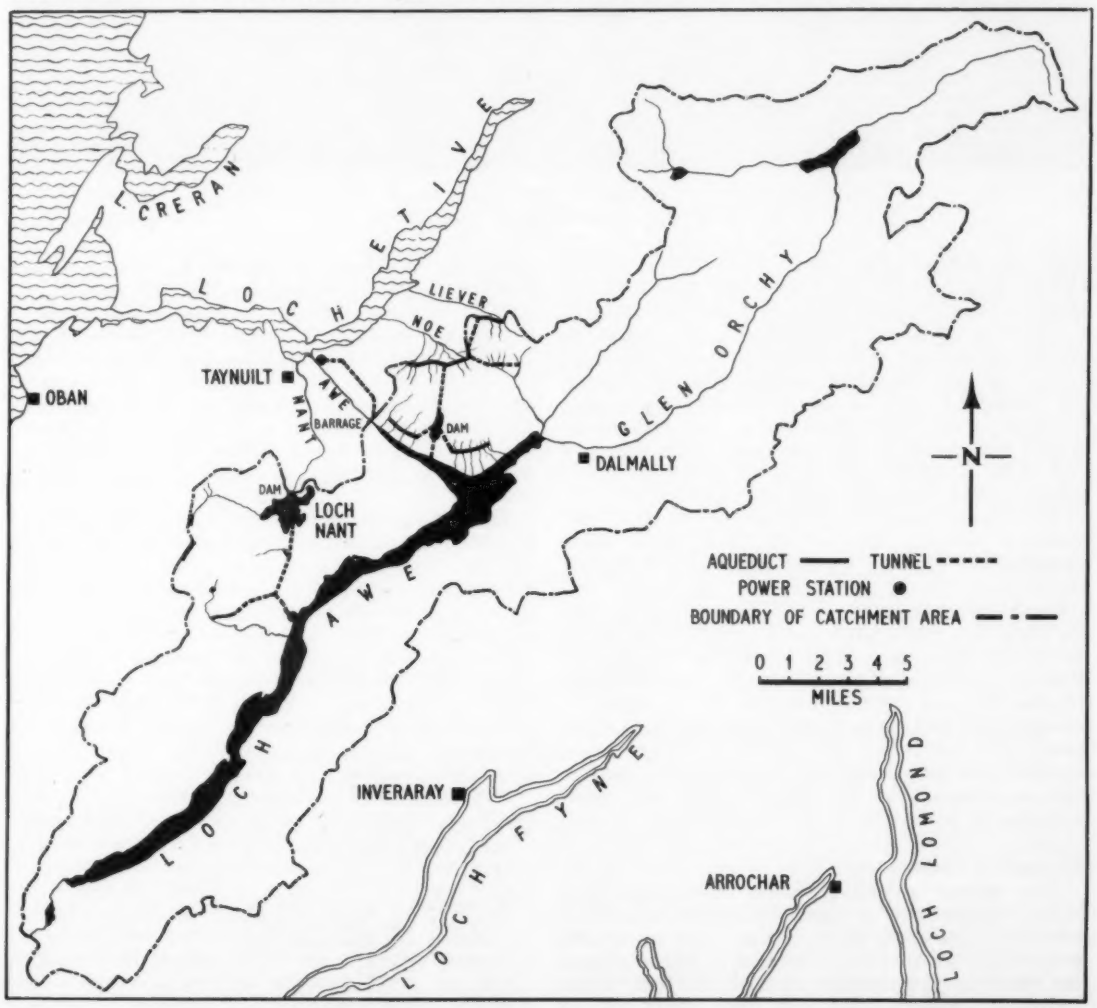


Fig. 2. General map showing the main features of the Awe project

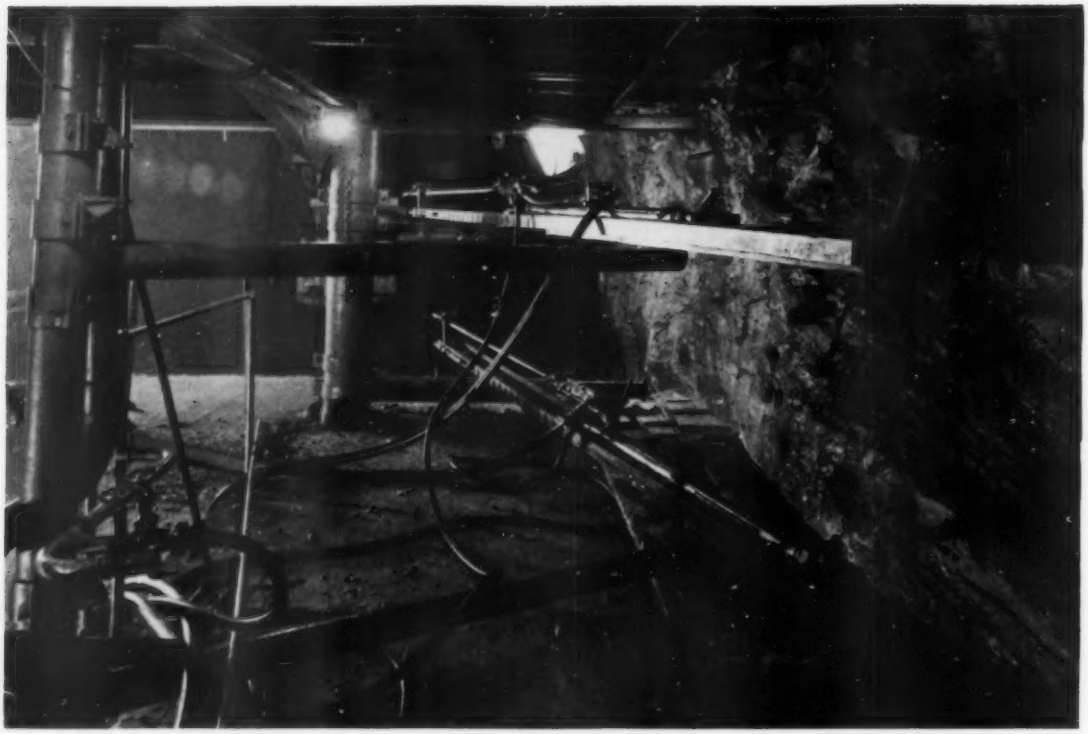


Fig. 3. The drilling ladders are shown mounted on fore and aft bars fitted to the platform. This arrangement facilitates the drilling of angle holes

that this will be the largest water tunnel in the United Kingdom. The low pressure tunnel has a slope of 1 in 500 to the point where the high-pressure tunnel turns off at approximately 45°, and where an unlined surge shaft is now being sunk from the surface above. The topography is such that the contractor elected to drive an access tunnel towards this junction on the same alignment as the low-pressure tunnel. Except for a short distance at the upstream end of the low-pressure tunnel, the rock is generally sound granite, which requires no support.

The access tunnel was driven using the conventional drilling method of light-weight drills mounted on ordinary pusher legs, but, thereafter, the ladder drilling method was employed. This method has been used in Sweden on large tunnels for some two years, particularly at Stalon and Korsselbränna, where it was introduced by Widmark & Platzer, civil-engineering contractors, and developed by that firm and the Swedish State Power Board, in co-operation with Atlas Copco AB. The method appears to be best suited to large-diameter tunnels, and the Inverawe tunnel contract probably presented the first opportunity for its application in the United Kingdom.

Method of Drilling

The system utilises standard light-weight rock drills together with a conventional type of drilling platform. The rock drills, which have retractable pusher legs of the type developed by Atlas Copco, are mounted horizontally on steel ladders. These consist of channels fitted with rungs about 50 mm long and spaced some 200 mm apart, and the rungs take the thrust as the pusher leg advances the machine. Lugs are welded to the claw foot of the retractable leg of the drill to provide the necessary anchorage for retraction. The drill slides on the ladder by means of a cradle, and collaring is simplified by the use of a drill-steel support, which can be extended according to the distance of the rock face. The ladders are mounted on forward and rear transverse bars rigged on the drilling gantry, and can be adjusted on these bars to allow for angle drilling (see Fig. 3).

The drilling platform used at Inverawe (see Fig. 1) has two decks, and drilling is carried out with 14

COMPARATIVE RATES FOR QUARTZITE DRILLING — NET DRILLING RATE: 50–55 cm/min

Method of drilling	Drilled metres/ man-hour	Increase in gross capacity*
A. Drilling with hand-held pusherleg machine. One man with one machine	19·5	
B. Drilling with rock drills mounted on ladders. One man with two machines	39	100%
C. Combination of A and B. One man with one pusher-fed machine and one ladder-fed machine	30·5	57%

* The gross capacity refers to the mean value for the whole drilling period including collaring, changing steels, normal interruptions and sundry delays.

drills operated by ten men. The two bottom rows of holes are drilled by ladder-mounted drills on the floor of the tunnel and slung beneath the platform. The next three rows are angle holes to form a V-cut, and the machines used for this work also drill the wall holes. Two rows of holes parallel to the drilling platform and two rows that follow the arch of the tunnel are drilled from the upper deck, which can be raised or lowered.

Some 94 holes are used on the Inverawe heading, and the advance has recently been averaging approximately 11 ft every 11 hours, the longest hole in the wedge being about 13 ft, and the best week's performance so far has been an advance of 123 ft in eleven 12-hour shifts.

The chief advantages claimed for the ladder-drilling method are accuracy of collaring and hole direction, reduction of manpower, fewer rod changes as longer steels can be used, and reduction of operator-fatigue. On the basis of experience at Inverawe, these claims would appear to be realistic. In particular, the accuracy of drilling combined with the use in the periphery holes of low nitroglycerine-content explosives has produced a high degree of finish to the tunnel, which may be favourably compared with the results obtained in the access tunnel. The reduction in overbreak resulting from the use of this method has been estimated to be as much as 18 in. No comparative productivity data are available for the Inverawe tunnel, but the results of a time and motion study during the drilling of a 60-m² tunnel in quartzite are given in the accompanying table.

Fig. 4. Two of the LM 250 loaders and the traverser used for mucking out

Spoil Removal

Mucking is carried out by 5-cu yard mine cars working on twin 3-ft gauge tracks. A traversing bridge is employed and loading is carried out by two 1 cu yard Atlas Copco LM250 loaders (see Fig. 4). Some 220 cu yards in the solid are pulled per round and the excavated material is hauled to a spoil tip on the shore of Loch Etive. A proportion of this rock is crushed and used as base material on the Cruachan access road.

The mucking cycle occupies about seven hours, during which about 90 car-loads are removed on average. Each car can be loaded in approximately two minutes and changed with the traverser in about one minute. By the end of 1960, approximately half-a-mile of tunnel had been excavated from the downstream end.

Punched-Paper-Tape Reader

The English Electric Co. Ltd. are now manufacturing as standard equipment, at their Data Processing and Control Systems Division at Kidsgrove, Staffordshire, a high-performance punched-paper-tape reader, originally designed for use with the DEUCE computer. The reading speed is up to 1,000 characters per second, and the tape can be stopped from full speed after reading any character without losing the next. It can be started and stopped up to a maximum of 30 times per second. An adjustment is provided to accept tapes of standard widths with five, seven, or eight code holes, and tape may be used from any stock, subject to certain limitations on translucency.

Magazines are available for fitting to the machine to allow repetitive reading of a loop of tape up to 100 ft in length, or to accommodate up to 300 ft of free tape which may then be rewound from the trailing end. Magazines are interchangeable and any number can be supplied for use with a reader. A replaceable plugboard allows rearrangement or omission of the bits within a character as read from the tape. Switches are provided that allow the operator to select odd or even parity checks or no check, and which cause any "all-ones" character to be ignored. The reader uses only transistor circuits; the sensing elements are phototransistors, which are compensated for temperature variation.

High-speed readers are now operating as part of six DEUCE installations, including those at Glasgow and Liverpool Universities, and are stated to have proved extremely reliable in operation. One is being fitted to the recently announced KDF 9 data-processing system.

Inframatic Moisture Tester

An infra-red moisture balance that has hitherto found application in industry for the rapid assessment of moisture contents in clays and slurries, but which appears to have a value in the civil-engineering field, is marketed by Shandon Scientific Co. Ltd., 6 Cromwell Place, London, S.W.7.

The processes of drying and weighing are carried out on the balance itself without disturbance of the sample, and the moisture content is indicated as a percentage reading on a calibrated scale, which, on the precision model, gives direct reading to 0·1%. The infra-red lamp enables extremely rapid drying

to be accomplished but the restriction on the size of the sample to 10 gm necessitates very careful sampling. The direct-reading moisture-content scale has the distinct advantage of ensuring that the sample has been fully dried. The only restrictions on the use of this instrument under site conditions are the necessity for an a.c. supply and the provision of a reasonably stable base for the balance.

New Doulton Insulator

Fig. 1. Insulator being assembled for testing

Fig. 2. A jolleyed section nearing completion

Voltages of the world's grid systems have now reached 400 kV and values of up to 700 kV are contemplated. At these voltages the design of suitable insulating columns or pillars for equipment such as disconnecting switches becomes increasingly complex if conventional methods are used. In particular, the space required for substations is causing concern as, for example, the normal 275-kV support insulator is some ten feet in height. A new insulator, which it is claimed will overcome many of the problems associated with increasingly high voltages, has been developed by Doulton Industrial Porcelains Limited, in association with Etablissements Merlin-Gerin of Grenoble, France.

The Doulton Multicone insulator (Fig. 1) represents an appreciable advance in the manufacture of equipment capable of dealing with these problems. In Continental stations, insulators constructed along similar lines have been employed extensively and successfully for a number of years, although these insulators have a lower mechanical rating and embody plain sheds instead of antifog construction.

The porcelain elements of the insulator are cones which fit into each other and which are bonded by cement joints. Thus, there is no internal creepage path which can be broken down. The puncture path is through many layers of porcelain and the voltage required to break down this path is extremely high compared with the external flashover value.

A major advantage claimed for these insulators is their low deflection under cantilever loading. It is well known that difficulty is experienced in obtaining low deflection figures with the normal pedestal-post assembly and this is due to the fact that the main loading parts are of metal and have relatively small diameters. For example, a 275-kV post of the conventional type to meet normal British Standard Specifications requires 14 metal components in addition to the top and bottom fixing flanges. The equivalent post of Multicone design uses only two, and, as a direct result, the deflection of the Multicone post is less than a third of a conventional post. This reduction in the number of metal components also enables the required creepage length to be provided with an assembly of appreciably less height than that of the conventional pedestal design.

Other features of the Multicone design are that the stress-grading ring is smaller in diameter than that of the orthodox pedestal post, the flashover values are appreciably higher than those of conventional design, and the long leakage path enables one inch per kV to be provided at high voltages, while maintaining the minimum height of post appropriate to the impulse-flashover level.

All the porcelain parts, which are comparatively small in size, can be made by the standard jolley process (see Fig. 2), which is a most reliable method of producing a consistent and high-performance porcelain article. Similarly, all parts are suitable for normal tunnel-kiln firing. The shape of the porcelain parts is

such that normal power-frequency or high-frequency routine tests can be employed.

The new product appears to offer some flexibility to the designer as it is possible to vary the characteristics of a post by the choice of the number of conical elements which are included in a unit assembly. Designs are already available for 275-kV and 380-kV applications, for use either outdoors or indoors, and the electrical and mechanical characteristics have been extensively tested. The Doulton Multicone post is now being manufactured in England under an agreement with Merlin-Gerin, whose insulators have been in use for many years on the French high-voltage grid.

B.S.P. Impulse Pile Driver

This machine has been developed by the British Steel Piling Co. Ltd., Haymarket, London, S.W.1, to drive piles by a rapid succession of impulsive forces. The prototype machine shown in the accompanying photograph is powered by two 30 h.p. electric motors and drives eccentric weights through chains and a linkage system designed to produce a rapid succession of downward impulses instead of a succession of blows as in the conventional pile driver. These downward impulses are of considerable magnitude and in fully developed machines may be up to 50 tons or more. The prototype machine, which was completed only very recently, has driven piles of Frodingham Section No. 3 in works-test conditions while operating at minimum power.

As the machine does not hammer the pile and is not driven by steam or compressed air, it is relatively noiseless in operation.

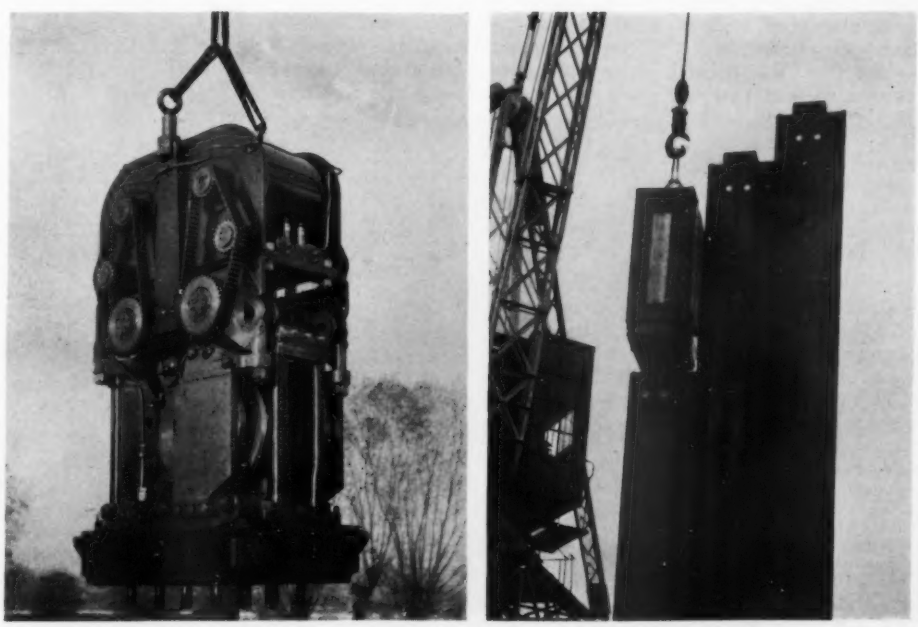
The clamping device used at present to connect the machine to the piles does not represent the final design. This will be in the form of a high-pressure hydraulically operated friction grip, which will connect the machine to the piles and which will be capable of releasing it almost instantaneously. The prototype is designed only for driving the piles, but further development work may permit it also to be adapted for pile extraction.

Raise-Climber Method Employed at Stalon

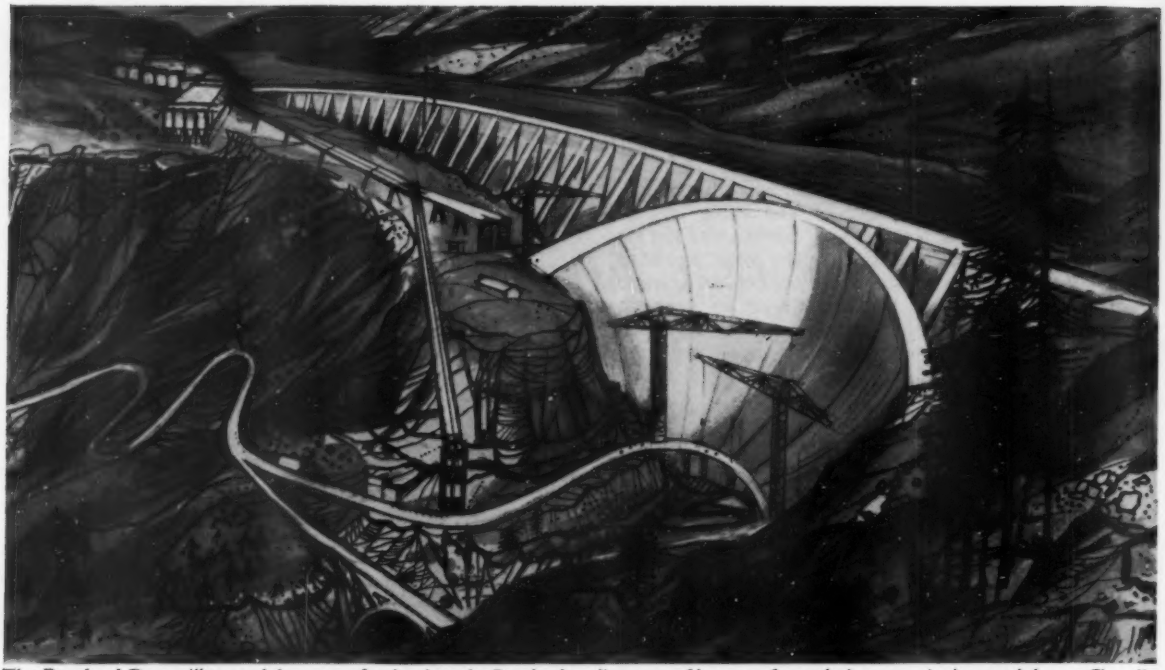
It is claimed that the adoption of a new tunnel-driving technique, based on the use of the Alimak raise climber, has cut the construction time for the high-pressure tunnel of the Swedish State Power Board's Stalon project by more than half. This technique, combined with other efforts to speed up work, is reported to have resulted in the reduction of the construction time for the 100-MW hydro development from seven to just over three years, and the station will now be commissioned in September 1961.

Stalon, which is the sixth of the State Power Board's power projects on the Ångerman River, North Sweden, presents a number of new solutions to the problem of joining up rock-based lake systems, and it has been possible to utilise the full 200-m head. The supply tunnel from the Kultsjön Lake reservoir to the power station at the Malgomaj Lake passes beneath the Njaka fjeld; it is 17·8 km long and has a maximum cover of 250 m of solid rock. At the end of the low-pressure tunnel, the water will flow into the underground power station through a circular pressure tunnel of 240-m length, and which is inclined at an angle of 47°. The low-pressure tunnel has a sectional area of 60 m^2 and has required the removal of over one million m^3 of rock. The high-pressure tunnel has a diameter of 6 m and will be lined with concrete.

The raise-climber device used for the driving of the high-pressure tunnel was developed a few years ago by Alimakverken, Skellefteå, mainly for application



Prototype impulse pile driver undergoing test



The Roselend Dam will control the waters flowing into the Roselend valley from the Beaufort massif. Other streams will also be diverted into the catchment area by means of some 60 km of collector tunnels (with diameters of between five and nine metres). A second dam at Chapelle de St. Guerin will control the waters of the Poncellamont Gorge. Illustrated above is an artists impression of the Roselend Dam.

FRANCE PUTS THE SAVOY ALPS TO WORK

Atlas Copco and Sandvik Coromant equipment used extensively at Roselend

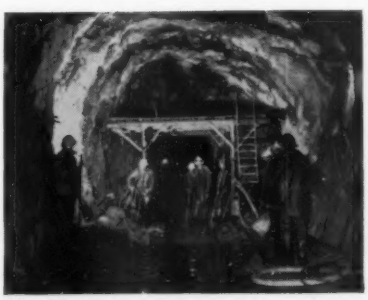
TO THE TOURIST, the Savoy Alps may conjure up visions of winter sports or long, lazy summer holidays, but to Electricité de France the region means power! The French State power board is building a series of storage reservoirs in the upper Isere area of the Alps, not far from the Italian border. The most important part of the scheme is the Roselend Valley section which will increase France's power reserves by 1,000 million kWh a year. This project involves building two dams and a 476,000kW power station at Bathie which will be the most powerful in France.

Atlas Copco compressed air equipment is being used almost everywhere on this project. For drilling the main tunnels more than a hundred BBD41WK rock drills with pusher feeds and several thousand Sandvik Coromant drill steels are being used by the main contractors, Borie, Ets. Seinrapt & Brice, Gebro, Pegas & Pugeat, Stribick Et Fils.

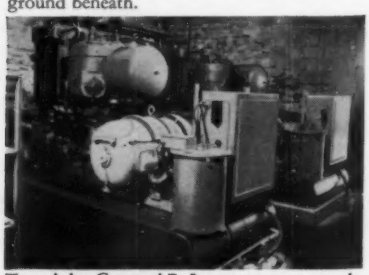
Sales and Service in 100 countries

Atlas Copco is the world's largest organisation specialising solely in compressed air equipment. Products include stationary and portable compressors, rock drills, loaders and air tools and equipment of every description. Wherever you are, the international Atlas Copco group will supply expert advice on the selection of equipment and provide a complete after-sales service.

General view of work on the Roselend Dam.



The Headrace Tunnel will be 13 km in length and 4.2 metres in diameter. Single deck platforms are used for drilling, with four men working on the platform and four on the ground beneath.



Two Atlas Copco AR3L compressors supply the air power at the Versoyen drilling site.

Atlas Copco puts compressed air to work for the world

ATLAS COPCO AB, STOCKHOLM 1, SWEDEN

DIA.1

in mines. The equipment was described in detail in WATER POWER, June 1959.

The driving of the high-pressure tunnel took only seven months, and it is estimated that the use of conventional driving methods would have required a construction time of about two years. Operations were also speeded up by the excavation of three adits, which made it possible to drive the tunnel from seven points simultaneously.

Low-Hydrogen High-Tensile Electrode

EutecTrode 66 is recommended by the makers, Eutectic Welding Alloys Co. Ltd., Faggs Road, Feltham, Middlesex, for joining low- and medium-carbon steels, crack-sensitive steels, free-cutting and problem steels such as those with a high sulphur or phosphorus content. It is claimed to have high ductility and excellent resilience even at very low temperatures.

The electrode is stated to have been developed for assembling and overlaying, and for fabricating and repairing steels up to 38 tons/in² in order to produce particularly tough and crack-proof joints, and could be applied, for example, in the case of carbon steels with a carbon content up to about 0·4%, and also low-alloy manganese steels, chromium steels, molybdenum steels and chromium-molybdenum steels. It is said to be suitable for malleable cast iron, as well as for the steel side of plated-steel sheet and padding prior to applying hard overlays. It is claimed to have proved excellent for structural steel fabrication, pipe lines and tubular work, fabricating pressure tanks, and in shipbuilding for steels with a tensile strength up to 38 tons/in². It is also being applied to such tasks as overlaying worn shafts and broken gear teeth.

Euclid TS-14 Scraper

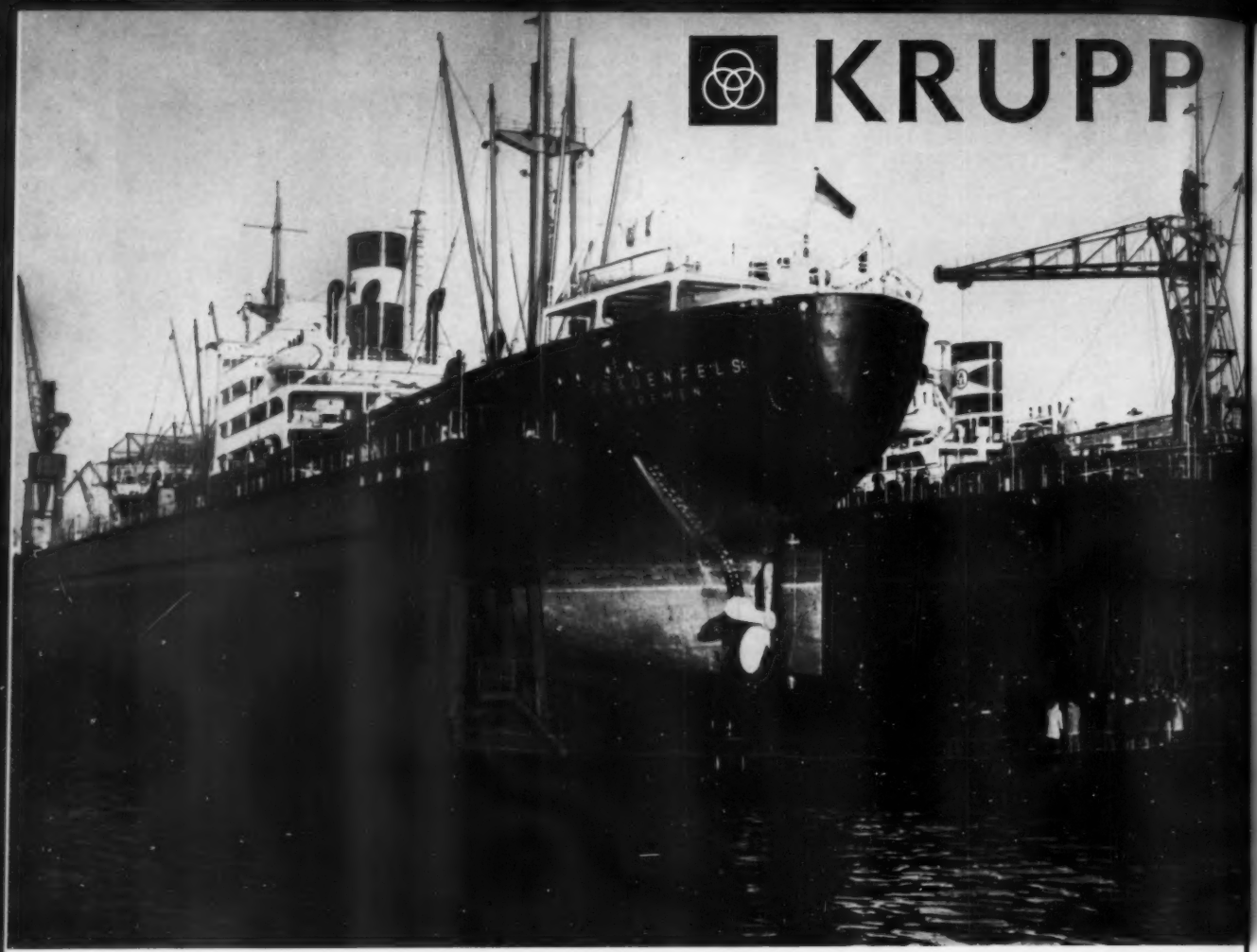
The advantages of Euclid twin-powered four-wheel drive are incorporated in this new British 280-h.p. 14–20 cu yard capacity scraper. Like the widely used TS-24 the machine has twin engines, one mounted forward and one aft, each of which drives its respective axle through a separate torqmatic drive and power train. Power-operated remote controls and full power shift enable operators to change without effort from one power range to another. The TS-14 is fitted with a new wide and low "easy load" bowl. This and the four-wheel drive enable the unit to load practically every type of scraper material under the most adverse conditions. All scraper operations are hydraulically and independently controlled. The cutting edge is of four identical sections, each of which is independently adjustable and reversible.

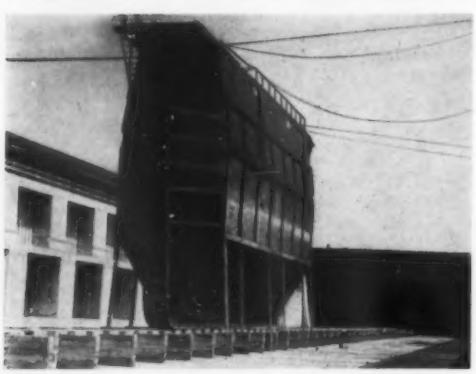
New Holman-Iberica Factory

A new factory for Holman-Iberica S.A. was recently opened at Pinto near Madrid by Mr. P. M. Holman, Chairman of Holman Bros. Ltd., of Camborne, Cornwall. Holman-Iberica was formed in 1957 by Holmans with their Spanish agents, Maclaurin Morrison y Cia S.A. and the latter Company's associates the Siberex Group. Although an obvious purpose of this venture was to overcome stiffening Spanish import regulations, the Company has already progressed to a point where greatly increased sales of Holman Group products in the Iberian Peninsula are evident.

Initial production was concentrated on air compressors; the first, with a capacity of 120 cu. ft. per min. and powered by a Barreiros diesel engine of wholly Spanish manufacture was completed in July last year. It was built from drawings and patterns supplied from Camborne, but all components except the valve assemblies were manufactured in Spain. Additionally, the manufacture of stationary compressors, Holsteels, Holbits and rock-drill spares is already well under way. The new Pinto factory will enable Holman-Iberica to increase both the quantity and range of their products. A larger-capacity Holman compressor, a range of pneumatic tools, and the Holman Silver Three Handril are all scheduled for production.

Euclid TS-14 280-h.p. twin-powered scraper





Floating Docks
Ship Lifts
Slipways
Floating Caissons
Floating Crane Pontoons

Top:
10,000-ton floating dock with ship docked
Centre:
Launch of a floating dock
Bottom:
Floating caisson for a dry dock; 109 ft. long, 17 ft. wide, 45 ft. high
Weight 570 tons.

FRIED. KRUPP MASCHINEN- UND STAHLBAU RHEINHAUSEN

U. K. Agents: J. M. J. Maus Ltd., 35 New Broad Street, London E. C. 2

Book Reviews

Irrigation and Hydraulic Design. Vol. 3: Hydraulic Structures for Irrigation and Other Purposes. By Serge Leliavsky, Ph.D., M.I.C.E., F.ASCE. Published by Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. 1960. 765 pp. (including index). 825 ff. 10 in $\times 7\frac{1}{2}$ in $\times 2$ in. 273s. net.

The final volume of Dr. Leliavsky's massive treatise maintains the high standards of the first two volumes*, and the praise for his work lavished upon Dr. Leliavsky in previous reviews is endorsed by a study of his latest book. If any criticism of the book as a whole is valid it must surely be levelled against the choice of title, which suggests a very much more modest scope than is actually covered by the work.

This volume is divided into five chapters, numbered from nine, each of which contains considerable information of direct interest to those engaged in hydro-electric work as well as irrigation. The first chapter, of some 150 pages, is devoted to the problems of diversion headworks, and the author has allotted a considerable proportion of this chapter to the extremely important topics of cut-offs and cofferdams, or "sudds" (Dr. Leliavsky employs the Nile terminology throughout). This section is enlivened by a reproduced description of the problems encountered during the construction of the Assiut barrage. Descriptive matter of this nature is probably the key to the author's literary success; by the timely presentation of practical examples he is able to provoke a livelier interest in the more abstruse portions of the text.

Chapter nine, which is concluded with a section on control gates, is followed by a chapter on locks, which will appeal to the specialists in this field as well as to those who tend to regard such structures as unfortunate complications in the design of dams and other control structures. Some 150 pages are then devoted to the subject of arches, and these include a lucid explanation of the elastic theory of design as well as a section on design procedure.

More than a third of the book is contained in the twelfth chapter, which is on dams. Included are two sections on the hydraulic and hydrological problems relating to dam design, and these, of course, cover the basic storage analyses. However, it is rather disappointing to find so little space devoted to the subjects of evaporation and run-off/rainfall relationships. It is not often that the designer of projects outside the USA, Europe, and the Nile basin is as well endowed with such relatively plentiful data as are available for those regions, and some guidance on recent developments in hydrological analytical technique would have been of considerable value. The remainder of the chapter is devoted to the design of dams, which Dr. Leliavsky broadly divides into gravity and arch structures, and here the author is clearly at his best. The chapter is concluded with a section in which buttress and hollow dams are uniquely described as "baroque tendencies" in the evolution of the gravity dam, and the author not only finds the uncommon adjective applicable but also gives an authority for its usage in a more complimentary sense than is usual. However baroque they may be, the buttress dams and other less-conventional structures are given the same careful attention by the author as the "classical" types.

The last chapter is entitled "Electrification of Irrigation Works" and one should not be misled by this title for, in fact, this is virtually a discussion of the civil engineer's aspect of hydro-electric practice as applied to surface hydro-electric stations, and all classes of turbines are considered. The section dealing with the design of power-station layout is particularly useful, including, as it does, details of reinforced-concrete design for such portions of the structure as the turbine floor. Detailed information on this subject is rare in textbooks, and the author's contribution is a useful one. Even more so is the whole section on vibrations in hydro-electric installations (which was first published as an article in WATER POWER, April and May, 1957). This is a topic about which the average civil engineer may feel somewhat apprehensive, but Dr. Leliavsky introduces it with remarkable simplicity, and many will be convinced by his reasoning that the careful design of power stations to allow for vibration stresses is an essential requirement. The chapter concludes with a brief discussion of new developments in power-station design, and this is largely devoted to tubular turbines, including their application to tidal power.

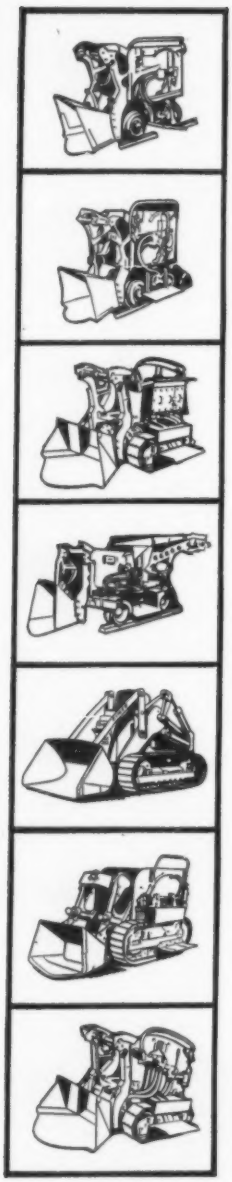
This highly readable textbook would be a worthy addition to any hydro-power engineer's library, not only for its wealth of detailed information but for its interesting approach to general principles. The author's happy knack of emphasising his design points with relevant background material has made it so. We may conclude by referring to the author's original preface in which he states that all technical books can be divided into two categories: those that are kept on bookshelves, and the few that always remain on the designer's desk. Dr. Leliavsky attempted to write his three volumes for the second category and we feel that he has been eminently successful.

Water Power Development, Vol. II (High-Head Power Plants, Midget Stations and Pumped-Storage Schemes). By Prof. Dr. Techn. Emil Mosonyi. Publishing House of the Hungarian Academy of Sciences, Budapest V, Alkotmány u.21. Collet's, 44–45 Museum Street, London, W.C.1. 1,140 pp. 742 ff. 4 supplementary plates. Price £6, $15.

An extended review of the German edition of this second volume of Dr. Mosonyi's series was published in our July 1960 issue, and the English edition differs so little from the German that we can hardly do better than refer our readers to that review. Nevertheless, an examination of the volume impresses us afresh with the author's thoroughness in dealing with his subject. As we stated in our earlier review, the value of his work lies not so much in its originality as in its comprehensiveness, and particularly in the attention it gives to recent trends. This is especially noticeable in the sections dealing with surge tanks, underground power stations, midget plants, and pumped-storage systems.

We have previously expressed our opinion that the chapter on waterwheel alternators might have been expanded, and we must confess that we are disappointed that the subject of turbine governing has been merely touched upon. But in a work of this

* Reviewed in WATER POWER, March 1955, p. 93, and April 1958, p. 150, respectively.



Wherever the going is tough you'll find an EIMCO

Tough conditions call for tough equipment—Eimco equipment. Whether it is a tunnel to be driven against the clock or a furnace to be repaired in a hurry Eimco loaders speed the job, cut costs and keep on loading no matter what the conditions.

If YOU have a tough job you can't beat an Eimco.

EIMCO (GREAT BRITAIN) LIMITED

HEAD OFFICE: TEAM VALLEY, GATESHEAD 11, CO. DURHAM. 'PHONE: LOW FELL 7-7241.
LONDON OFFICE: PRINCES HOUSE, PICCADILLY, W.1. 'PHONE: REGENT 2184

P3461

magnitude some scantiness of treatment here and there is inevitable.

A third and final volume is now in preparation to cover river barrages, high dams, steel structures and mechanical equipment, operation and maintenance, and economic questions. When this volume has been published, Mosonyi's "Water Power Development" may well take its place beside Creager and Justin's "Hydro-Electric Handbook," Guthrie Brown's "Hydro-Electric Engineering Practice," and Leliavski's "Irrigation and Hydraulic Design" as one of the world's standard reference books on the subject.

Druckstollenbau (Design and Construction of Pressure Tunnels). By A. Kieser. Published by Springer-Verlag, Mölkerbastei 5, Vienna 1, Austria. 1960. 218 pp. 135 ff. Price £4 12s. 0d.

The author is well known for his pioneering work in the design and construction of prestressed pressure tunnels for hydro-power development in the Austrian Alps. Tunnel designers will take great interest in a treatise written by such an experienced and knowledgeable specialist.

The book is divided into eight chapters. The main Chapter 4 (pages 63–173) describes the different types of pressure tunnels, especially the different types of tunnel linings. The author has only a few words for unlined tunnels and does not mention some remarkable unlined tunnels and pressure shafts built in Scotland, Sweden, and elsewhere. Ordinary concrete lining and steel lining are dealt with in detail in about 25 pages. More should have been said here on tunnelling experience in difficult rock; the main interest of the author is obviously in the different types of prestressed tunnel linings as used in Germany and Austria. (A detailed account of the test, carried out in the Roselend test gallery, is given in Chapter 5.)

Seven ordinary tunnels and four prestressed tunnels are described at full length in Chapter 5. Most of this material has already been published elsewhere, but it is of great value to have it all carefully analysed and systematically collected in one treatise by an experienced author. Let us regret that he does not mention some remarkable Canadian achievements (Kemano, Chute des Passes); the Scandinavian tunnelling technique (pressure tunnels and free-flow tunnels, lined or unlined) is hardly mentioned; some interesting French and Italian experience mainly in difficult rock could have been added in this chapter.

The author obviously had to limit the scope of his treatise and make a choice among many possible examples. He concentrates on those he knows best.

The first three chapters of the book are less convincing than Chapters 4 and 5. They deal mainly with the theory of tunnel design and with rock mechanics. So does Chapter 6. The author's treatment is in many aspects interesting (e.g., his treatment of pore pressure and uplift in fissured rock), but he ignores one modern school of thought, best represented by the brilliant treatise of J. Talobre and developed by others in a series of important papers. For this school of thinkers, rock prestressing, as introduced first by Heim and R. Fenner, later by Terzaghi, is of major importance for estimating the rock strength and the stability of tunnels. None of these papers is mentioned and the author does not say if he approves or disapproves of this modern approach to rock mechanics.

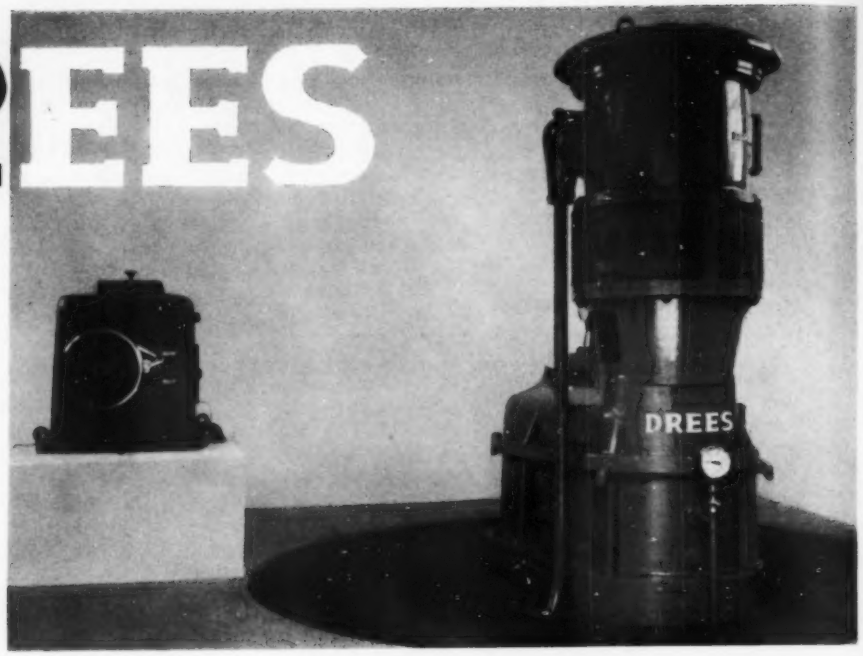
To any engineer involved in problems of tunnel design, the chapters dealing with the practical aspects of tunnelling will make most interesting reading. Differences of opinion on theoretical points should not reduce the importance of this publication.

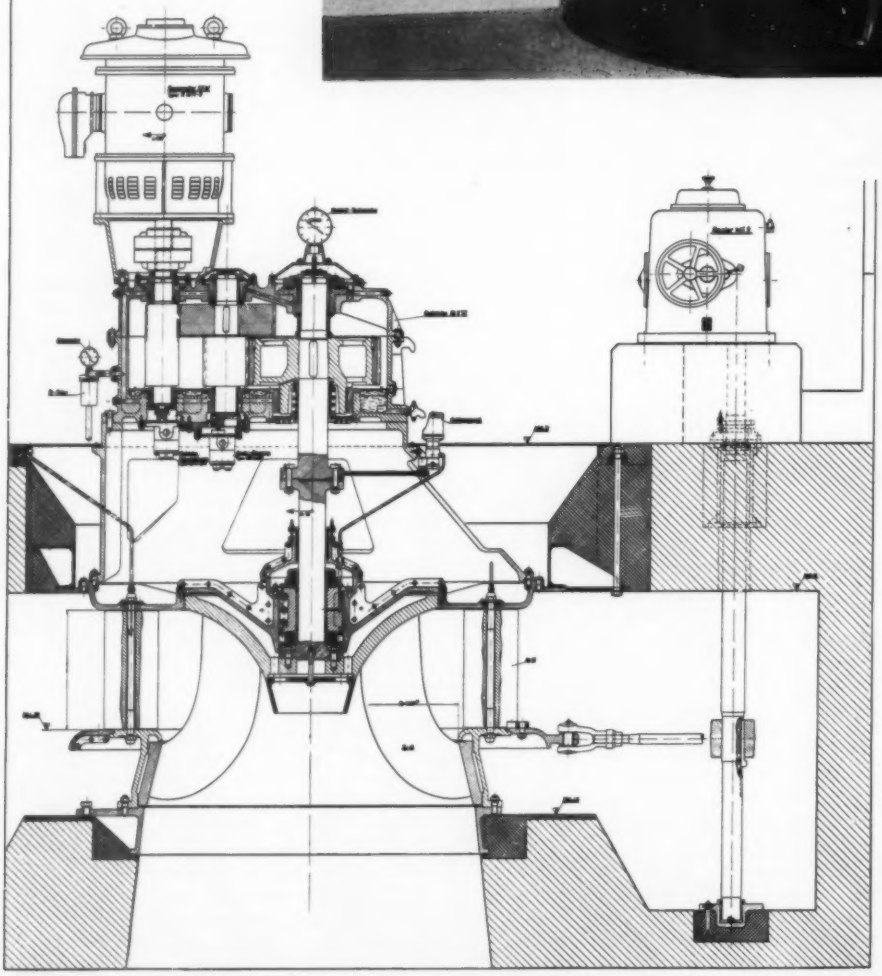
Abstracts from the World Technical Press

Harnessing the Arnon-Diablerets Head

The third instalment of this article deals exclusively with the Diablerets power station and its mode of operation. Layout and equipment have been conceived with a view to fulfilling the two major conditions which from the outset governed the planning of the Grande Eau development: (a) harnessing for power purposes the water drawn from the Arnon Lake to ensure in winter the regulation of the supply to Pont de la Tine and Farettes, the two downstream plants; (b) operation by remote control from Pont de la Tine. In addition, owing to the absence of a surge tank at the head of the penstock, the constructional solutions adopted had to ensure unusually long opening, closing, and regulating times for all valves and other control elements operating in conjunction with the penstock, so as to keep waterhammer in any circumstances below the admissible limit. The longitudinal axes of the building and of the tailrace conduit are in a line with the penstock, and there is a single generating set, which consists of a two-nozzle Pelton turbine coupled to a three-phase alternator with its exciter and a small pilot alternator. The entire assembly is mounted on two bearings fitted one on either side of the alternator. The downstream end of the penstock, 70 cm in diameter, leads to the 55-cm spherical valve through a reducing section. To increase the efficiency of the turbine at small loads, the first nozzle opens alone at discharges from 0 to 50%, the second following automatically as soon as the discharge rises up to 1·75 m³/sec. The turbine output is 7,000 h.p. at 500 r.p.m. and at a discharge of 1,750 lit/sec. The wheel is of stainless steel and is cast in one piece. The gross and net heads are: full lake, 377 and 336 m; empty lake, 343 and 302 m. The alternator is rated at 5,300 kVA three-phase, 6,000 V, 50 c.p.s. The turbine discharge, before reaching the 190-m tailrace conduit, falls into a sump below the turbine. When the turbine is in operation this sump is full, but it empties during stoppages through a 100-mm hole at the bottom of the weir which separates it from the stilling and gauging chamber. To avoid the formation of ice during severe winter periods, all the installations between the nozzles and the Grande Eau empty entirely as soon as the generating set stops. The control room on the upper floor of the building houses all the metering and protective instruments, as well as the relays which receive the orders given from Pont de la Tine. An extensive signalling system retransmits to Pont de la Tine all the orders carried out as well as adjustments effected. The control system also discriminates between slight and serious faults, and, in the latter instance, switches the machine involved out of the network, brings it

DREES





DESIGNS AND CONSTRUCTS:

FRANCIS,
KAPLAN,
AND
PELTON
TURBINES
WITH HORIZONTAL AND VERTICAL SHAFTS

HYDRAULIC SPEED, HEAD WATER LEVEL AND SAFETY GOVERNORS

FLOW CONTROL EQUIPMENT GEARS

DREES + CO. GMBH WERL, WESTFALEN WESTERN GERMANY

rapidly to a standstill, suppresses excitation, operates the firefighting installations, and gives the alarm. To simplify the task of the control personnel at Pont de la Tine, the orders given by them are retransmitted and executed automatically by the Diablerets control room. This is illustrated by a detailed account of an instance in which the generating set is put into operation while the Grande Eau supplies the 1,500 lit/sec required by the downstream plants. In addition to the full telemetering, telecontrolling, and telesignalling systems, there is a private five-line telephone exchange at Diablerets with 11 stations between Lake Arnon and Pont de la Tine. (R. Rau and J. Lüdecke, *Bulletin Technique de la Suisse Romande*, Vol. 86, No. 20, September 24, 1960, p. 321, 11 pp., 9 ff.)

Snowy-Murray Development

A short account is given of the modified scheme for this development, on the first phase of which construction work was planned to start in 1960/61. The main modification consists of raising the diversion tunnel system to an elevation 700 ft higher than that contemplated in the original plan, which visualised diversion from Jindabyne reservoir, in which all Snowy water would have been stored. Now only the Snowy water below Island Bend will go to Jindabyne reservoir, which will be reduced in capacity from 1 million to 250,000 acre ft. Another major feature of the new layout will be a tunnel, in which water will be able to flow in either direction, connecting Island Bend with Lake Eucumbene, so that Lake Eucumbene will become the key storage reservoir of the scheme. As in the original proposal, the high-level layout, as it is called, includes a dam and reservoir on the Geehi River. The site, however, has been shifted four miles farther upstream in order to avoid a landslide area. Water will be pumped from Jindabyne to the tunnel system near East Bend during the night and at week-ends when cheap off-peak energy is available, and then diverted to the relocated Geehi reservoir for the production of peak energy in the western power stations. The main power development in the modified layout is a two-stage development, very similar to the original scheme, between Geehi reservoir and the Swampy Plain River near Khancoban. The major advantages brought about by these modifications are that Snowy water, which would otherwise have been wasted, will be utilised at least two years earlier, and a larger amount of power and water for irrigation will be available at drought periods. (*Australian Civil Engineering*, Vol. 1, No. 10, July 4, 1960, pp. 46–49, 3 ff.)

Prospects of Water-Turbine Development

A concise survey is given, by one of the leading European experts in turbine design, of the stage reached in the development of the Francis, Kaplan, and Pelton turbines, and of the possibilities of future development. Hardly any further progress is to be expected in efficiency and specific weight with units of conventional design, and efforts are now mainly directed towards achieving a substantial reduction of initial and operating costs of hydro plants. These efforts are marked by the introduction of larger units operating at higher specific speeds, and by the adoption of simplified designs and improved manufacturing techniques. Unit capacity now frequently exceeds 100 MW, whereas 3 MW was considered a maximum fifty years ago. A chart illustrates this trend, and also shows how competition between the three established types has evolved. The Kaplan, with heads of up to 60 m and even 80 m, now encroaches more and more upon the medium-head range, in which the Francis turbine had practically a monopoly, while the latter seriously threatens the position of the Pelton wheel in high ranges of up to 500 m. In this connection, the advance of the Francis turbine is also supported by the fact that it is much less prone to wear and tear than the impulse machine. Points of weakness in this respect in Francis units are the runner blades, guide vanes, and labyrinth seals. The service life of the blades and vanes is considerably increased, however, by the use of stainless steels, and wear in labyrinth seals is almost eliminated by injecting under pressure into their first stages a quantity of water slightly in excess of the flow passing through it. With regard to building expenditure and equipment costs, the high speed of the Francis turbine is advantageous not only in reducing the weight and price of the machine but also in reducing the cost of the generator and the size of the power house itself. However, to overcome cavitation, Francis units, except in the case of submerged plants, must be set at a greater depth, thus entailing higher building costs. The present general tendency is to use Pelton wheels in connection with the highest heads only, and this has caused the vertical-shaft, multi-nozzle unit, to lose ground to the horizontal-shaft layout. In instances when two nozzles are required, the solution generally adopted is to drive, each with one nozzle, two wheels mounted symmetrically at either end of the generator shaft, the buckets being subjected to the impact of only one jet, and thus suffering less wear. Even with efficient sand traps inserted at the intake, and the use of stainless and high-grade steels, erosion by sandy water is unavoidable, and repair by welding or complete renewal of the affected components is necessary every year. In the USA, five years of service is considered a satisfactory performance for Pelton wheels protected by coats of stainless steel applied by welding. In reaction turbines, the head under which they can operate is restricted by cavitation. An increase in head for Kaplan units implies not only higher strength design requirements but also a greater number of blades in the runner. Furthermore, blade adjustment necessitates a larger hub diameter, while the radial blade length is reduced and the resulting blade-edge losses impair the efficiency of the machine. At the present juncture, 80 m appears to be the maximum head utilised by Kaplan units; at higher heads, the Dériaz machines with mixed-flow runners and blades moving on oblique axes, are superior. Higher speeds in Kaplan units, resulting in lower operating costs, have made further advances towards higher heads inevitable. One frequently applied design, which is similar to the invention patented long ago by Professor J. Kieswetter, Brno, consists of mounting two blades on each pivot-pin. This design has been further developed by Michanovski in the Soviet Union and may find its application in actual practice as soon as means have been found to check the deterioration of Thoma's figure. Blades of appropriate profile and suitable thickness, and which are highly resistant to cavitation, may be the answer to this problem. Emphasis is laid on the application of improved welding techniques to various parts of the turbine, as well as on the

importance of careful control tests and radiographic examination by betatron. Electronic computers may also contribute to the advance in turbine design. In Czechoslovakia, computers have been successfully used in connection with the design of the scroll of the pump intended for the Amalienhöhe storage pumping plant in Eastern Germany. Finally, the author draws attention to the possibility of reducing costs by further simplifying designs, a process which, while dispensing with some components, may lead to new types, such as direct-flow turbines, which have already found a successful application in the low-output range. (Prof. Ing. Miroslav Nechleba, *Czechoslovak Heavy Industry*, No. 7, 1960, p. 2, 3 pp., 4 ff.)

Penstock Welding Techniques

The tendency in hydro-electric developments to increase unit capacities is affecting penstock construction techniques due to the resulting increase of the parameter "construction pressure × diameter." The use of highly resistant and thermally treated steel plates leads to technically feasible and economic solutions, but it entails much more exacting demands on welding technique. For example, the weld steel must be adapted as closely as possible to the basic steel, the welded assembly requires the most careful investigations in all its construction details, and the material used must be the best available so as to enable the most economical methods of welding to be applied. The coefficient of weldability introduced into calculations takes into account the quality of resistance of the material used, and even more important is the consideration of other properties of both basic steel and weld steel, such as resistance to breaking caused by faulty welding, sensitiveness to ageing, weldability, and other factors. It is now possible to apply higher calculation stresses, but on the other hand more numerous and more efficient methods of control must be made available. For all parts submitted to high pressures the mechanical testing of the weld seam must be supplemented by a thorough non-destructive control. In this connection, ultrasonic control offers important advantages over X-ray testing, and, above all, in relation to the hydraulic-pressure test. After five years of a widespread application of ultrasonic tests to penstocks, the quality of weld seams has considerably improved. (Jürg Bienz, *La Technique de l'Eau*, Vol. XIV, No. 165, September 15, 1960, p. 45, 8 pp., 5 ff.)

A New Chemical Grout

This is a short note on the AM-9 chemical grout which is claimed to turn water into a stiff gel. Obviously such a water-solidifying grout may prove exceedingly useful in excavation work connected with hydro-electric developments. In fact, it has been field tested in tunnels and cofferdams, and was recently employed at Rocky Reach dam on the Columbia River for the curtain wall formed in the east bank. In this particular instance, cement-clay and cement-bentonite grouts were used in the first place, followed by the low-viscosity chemical grout which was injected to penetrate sand zones of low permeability. The material, a water-soluble mixture of two organic chemicals, is available as a white powder. An aqueous solution of the chemicals and a catalyst are mixed at or near the injection point in a container in which the solutions are kept separate until just prior to injection. (*Engineering News Record*, Vol. 165, No. 5, August 4, 1960, p. 56, 4 ff.)

Engineering Studies of the Fraser River Basin

Adequate control of the Fraser River against a design flood greater in magnitude and volume than any known discharge could be realised through a system of power and storage dams located throughout the main river and its tributaries. Such a system would not only keep the freshet flows in the Lower Fraser Valley within the capacity of the existing dyke systems, but would also be economically self-supporting through the sale of electrical energy. However, the three suggested systems, each with over 5 million kW of firm power, do not include fish facilities, which were omitted primarily because of lack of pertinent information on all factors involved. This led the Fraser River Board to a study of partial developments of the three main systems, which, while having a minimum adverse effect on the fishery resource, would be part of the overall system in which flood control would still be realised, while the total cost would still be borne by the sale of electrical energy. The preliminary investigations carried out in support of these conclusions revealed a lack of representative meteorological data, which has been partially corrected through the introduction of a snow survey programme. Similar lack of hydrometric data or only short-term records necessitated correlations with older stations to obtain 20 years of continuous discharges. (T. A. J. Leach, *The Engineering Journal*, Vol. 43, No. 3, March, 1960, p. 59, 9 pp., 7 ff.)

Flow in Open Channels

This study relates to the vertical distribution in turbulent flow of mean velocity in an open channel. In his paper "The Structure of Turbulent Shear Flow," A. A. Townsend has worked out equations for turbulent flows in pipes and channels, for the conditions when flow occurs between rigid boundaries, and hydrostatic pressure is not effective. In this paper, the author uses the same methods as Townsend and gives velocity distributions for two cases: firstly, when the entire flow is governed by a single law, and, secondly, when the flow near the boundary and the flow away from the boundary follow different laws. Parabolic distributions are evident in both instances, but the accuracy in the latter case is more pronounced. Comparison of the results with available experimental data shows good agreement. (N. V. Chandrasekhara Swamy, *Irrigation and Power*, Vol. 17, No. 2, April, 1960, p. 190, 8 pp., 1 f.)

CLASSIFIED ADVERTISEMENTS

Announcements for this column can be accepted up to the 8th of the month for the following month's issue. The charges are fourpence per word with a mimmum of 10s. Box No. facilities 2s. 6d. extra. In order to avoid accountancy it would be appreciated if instructions to insert were accompanied with remittance.

Displayed classified advertising for situations vacant, situations wanted, public appointments, are accepted at £2 10s. 0d. per column inch.

Plant for Sale

DIESEL ALTERNATOR SETS from 75 to 450 kW in stock. We also purchase diesel engines and generating sets. Sippy, 118 Pepys Road, London, S.W.20.

KELSEY MANITOBA

Another

Major Turbine Installation by

DOMINION

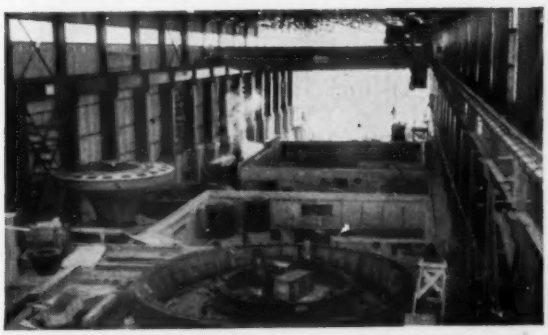
Projects of the magnitude of Kelsey require rigid adherence to tight construction schedules. As a major supplier, Dominion delivered its turbines to site on or before the dates set by The Manitoba Hydro-Electric Board, to have all installations completed on or ahead of schedule.

This achievement is particularly remarkable since Kelsey is the largest Canadian power station north of latitude 55°, and the remote location added to the normal difficulties of erection and transportation.

The five Dominion Propeller Turbines at Kelsey have an aggregate rated capacity of 210,000 HP.

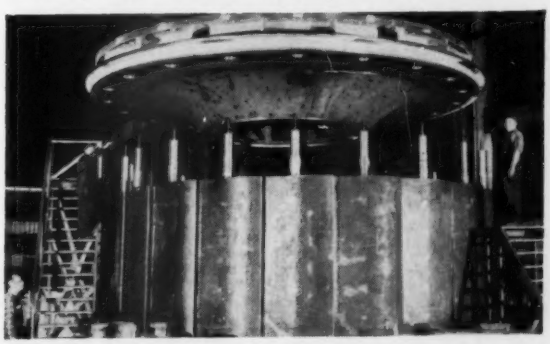
**Photos courtesy Manitoba Hydro-Electric Board.*

Kelsey Power House during construction.*



Power House Interior during construction.*

Runner, Hub and Head Cover prior to installation.*



Wicket Gate and Head Cover Assembly in the Dominion Plant.

HYDRAULIC DIVISION

DOMINION ENGINEERING COMPANY LIMITED

P.O. Box 220, Montreal, P.Q. Toronto — Vancouver

BUILDING FOR POWER

Huwood Conveyors are in wide use, not only in Britain but throughout the world—one of their most important applications being in the work of dam building for hydro-electric schemes.

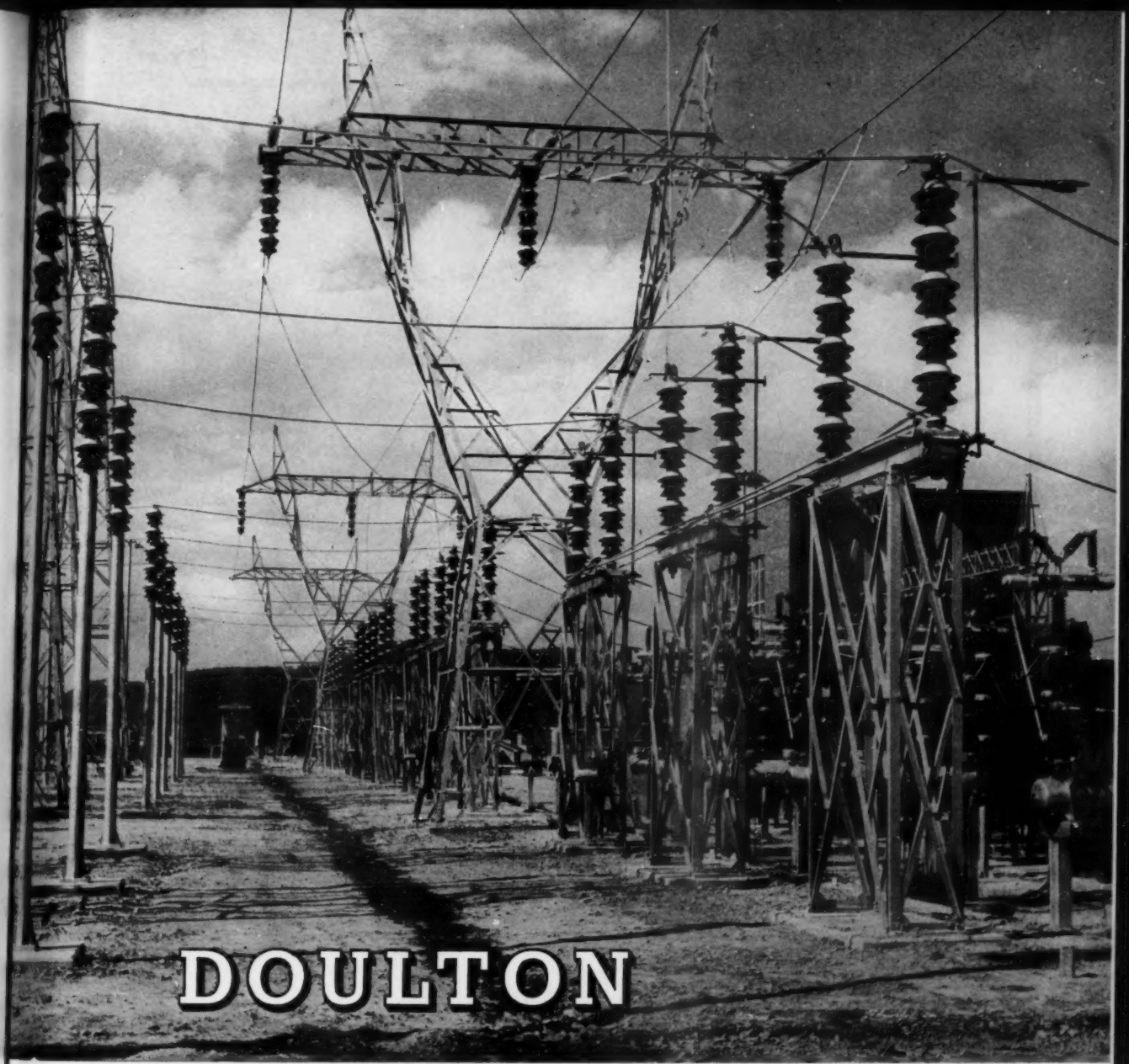
They have been chosen because they offer the highest degree of adaptability to varying sites, the utmost reliability, and the minimum of routine maintenance.

Huwood Conveyors

HUGH WOOD & CO. LTD.

Head Office and Factories
GATESHEAD-ON-TYNE, 11
Telegrams: Huwood, Gateshead. Telephone: Low Fell 76081 (5 lines).

Industrial and Export Office
ROYAL LONDON HOUSE, FINSBURY SQUARE, LONDON, E.C.2.
Telegrams: Huwood Stock, London. Telephone: Monarch 3273 (4 lines).



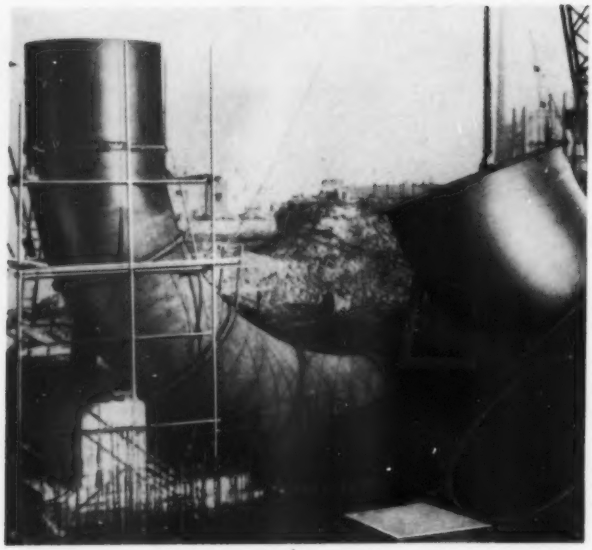
INSULATORS

220 kV in Tasmania

Doulton BB 26 post insulators, for 220 kV working voltage, installed at the Chapel Street sub-station near Hobart of the Hydro Electric Commission of Tasmania. This station will eventually be enlarged to 560 MVA to supply the Hobart district.

DOULTON INDUSTRIAL PORCELAINS LIMITED

ROYAL DOULTON POTTERIES WILNECOTE · TAMWORTH · STAFFS.

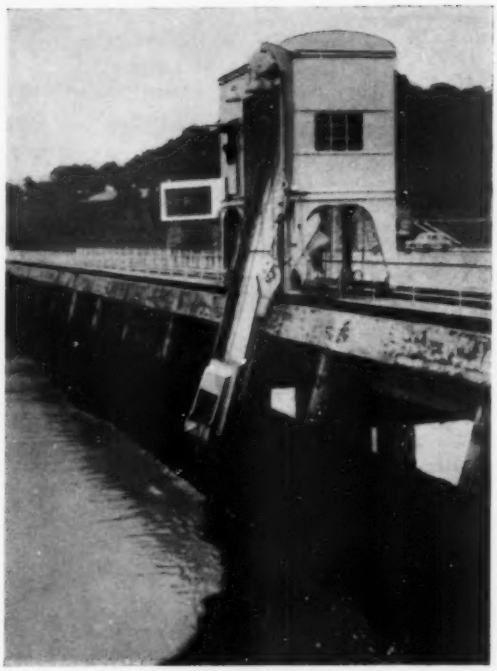


FABRICATED PIPEWORK

Steel Piping, riveted or welded; straight lengths, bends and specials, from 10 in. diameter upwards. Standard or special joints supplied. Pipeline construction in any part of the world.

MECHANS LIMITED

SCOTSTOUN IRON WORKS, GLASGOW, W4.
Telephone: Scotstoun 2211



Racks and
Rack Cleaning Machines

for

HYDRO-ELECTRIC POWER PLANTS
WATER PURIFICATION PLANTS
PUMPING STATIONS

ENGINEERING WORKS

JONNERET S.A.

GENEVA (JUNCTION) SWITZERLAND

CHARMILLES

HYDRAULIC TURBINES

—CHARMILLES ENGINEERING WORKS LTD., GENEVA—

TWO 88,000 HP VERTICAL SHAFT, FOUR-JET IMPULSE TURBINES FOR BRAZIL

RIVER SEVERN
CROSSING TOWERS
500-FT. HIGH

Main Contractors: J. L. Eve Construction Co. Ltd.

By courtesy of Central Electricity Generating Board

Tees Side Bridge

& ENGINEERING WORKS LTD.,

MIDDLESBROUGH. TELEPHONE: 45501-6

LONDON OFFICE: 56 VICTORIA STREET, S.W.1. TEL: ABBey 1613

BALFOUR BEATTY & CO. LIMITED

CIVIL AND ELECTRICAL ENGINEERS AND CONTRACTORS

Comprehensive Engineering Service for projects in all parts of the world

Head Office: Bow Bells House, Bread Street (Cheapside), London, E.C.4.

Overseas

CANADA : EAST AFRICA NIGERIA

MALAYA : PAKISTAN : IRAQ

Type U106 (0.6m³) Hitachi Power Shovel

HITACHI CONVERTIBLE SHOVEL

There's little glamour about a machine designed for engineers by engineers—men who are unsatisfied with anything less than constant, top efficiency.

The rugged Hitachi Convertible Shovel has been built for smooth and fast operation under the toughest conditions, from the tips of its wear-resistant cast steel dipper teeth to its stable, extra long and wide truck frame. The versatile Hitachi Convertible Shovel offers a choice of diesel engine or electric induction motor as prime mover, can be mounted on crawlers or truck for still higher mobility. The efficient Hitachi Convertible Shovel converts quickly and readily to dragline, drag shovel, clamshell, crane or piledriver. Literature and quotations gladly supplied on request.

Hitachi, Ltd.
Tokyo Japan
Cable Address: "HITACHY" TOKYO

It's a matter of experience

WHITES *of Widnes*

Ninety years' experience in the manufacture of Aerial Ropeways has given the "Whites of Widnes" organisation a knowledge of problems second to none.

ESTABLISHED 1869

R. WHITE & SONS (Engineers) LTD.

P.O. BOX 2, WIDNES, LANCASHIRE

Telegrams: "RAILS, WIDNES" *Telephone:* WIDNES 2425 (Three lines)

SPRINGER

PACKINGS

AND SEALS

FOR MOVABLE

ENGINE PARTS

HUHN

GUSTAV **HUHN** STOCKHOLM-Ö

SANDHAMNSGATAN 62

TEL. 610124 · 610132 · 616611

THE RAILWAY GAZETTE

A journal of Railway Management, Engineering, Operation, and Railway News. It covers every phase of railway activity. It is truly said of this journal that it is "Read wherever there are Railways." *Weekly* 2s. *Annually* £5 *by post.*

DIESEL RAILWAY TRACTION

A monthly review of world-wide developments in diesel-engine design, practice, and maintenance and diesel railway traction operation. *Monthly* 2s. 6d. *Annually* 35s. *by post.*

SHIPBUILDING AND SHIPPING RECORD

The only publication with direct appeal to both shipowner and shipbuilder. Its world-wide news organisation and technical articles and drawings put it in the forefront of shipping periodicals. *Weekly* 2s. *Annually* £5 *by post.*

COLLIERY ENGINEERING

A practical journal dealing with all aspects of coal production; every branch of coal mining technology is reviewed in detail and special attention is given to mechanisation and labour-saving machinery. *Monthly* 2s. 6d. *Annually* £2 *by post.*

COKE AND GAS

A technical journal dealing with the scientific and technical problems involved in the production of coke and gas in coke ovens and gasworks. *Monthly* 2s. 6d. *Annually* 35s. *by post.*

THE RAILWAY MAGAZINE

A popular magazine containing illustrated articles on Railways and Locomotives. *Monthly* 2s. 6d. *Annually* 35s. *by post.*

NEW COMMONWEALTH

Describes and illustrates significant developments in production, trade, transportation and related spheres in all countries of the Commonwealth. *Monthly* 2s. 6d. *Annually* £2 *by post.*

THE INDUSTRIAL CHEMIST

A technical journal devoted to the progress of applied chemistry and chemical engineering. It is of vital importance to the chemical manufacturer and all who employ chemical processes in their productive operations. *Monthly* 2s. 6d. *Annually* £2 *by post.*

WOOD

"Wood" is the only magazine of its kind. Primarily concerned with the use of wood, it includes articles on trees and timbers, design and construction in all decorative and practical wood usage, machines and machine practice, and trends in world supply. *Monthly* 2s. 6d. *Annually* 35s. *by post.*

FOOD PROCESSING AND PACKAGING

A journal devoted to the manufacture, packaging, and marketing of processed foodstuffs. *Monthly* 2s. 6d. *Annually* £2 *by post.*

WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development. *Monthly* 2s. 6d. *Annually* £2 *by post.*

MINE AND QUARRY ENGINEERING

Articles of technical nature cover geology, modern methods of prospecting, the winning of ore and stone, the dressing of ore and minerals, and extraction metallurgy. *Monthly* 2s. 6d. *Annually* 35s. *by post.*

TOTHILL PRESS LIMITED

33, Tothill Street, Westminster, London, S.W.1

Butterfly Valves are not what they used to be

72" diameter tight closing Butterfly Valve for 730 ft. hd. operating pressure.

There's hundreds of uses for **GORDON VALVES**

The old orthodox design of butterfly valves with all their inherent weaknesses are now things of the past. A completely new and patented bridge bearing system is incorporated in Gordon Butterfly Valves enabling very high pressure drops to be easily and smoothly controlled.

These design principles together with a choice of tight sealing methods which completely eliminate any shaft or peripheral leakage greatly extend the range of applications, and today Gordon Butterfly Valves are being specified in a wide range of industries from iron and steel works to nuclear engineering and wind tunnel operations.

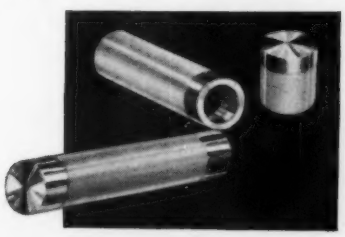
Available in sizes from 6" and upwards (standard designs include a 108" diameter valve), standard or purpose made, and in materials to suit almost any application, they could well play an important part in your organisation. *Full details supplied on request.*

A member of the Elliott Automation Group. EA

JAMES GORDON VALVES LTD · AIRPORT WORKS · ROCHESTER · KENT
Telephone: Chatham 44400

c/2

Continuous performance!



continuous cast rods and tubes

CUT COSTS FOR PHOSPHOR-BRONZE BUSHES AND BEARINGS

Continuous cast phosphor-bronze rods and tubes by the 'BIRSO' technique offer considerable advantages in cost and superior physical properties.

Since the rods and tubes are supplied in exact lengths up to 12 ft. there is negligible waste of bar ends. ● No sand core used. ● Porosity is entirely eliminated. ● Greater impact strength, tensile strength, yield stress hardness, better fatigue characteristics, and improved uniformity.

Phone or write for complete specifications of our continuous cast phosphor-bronze rods and tubes together with details of our precision machined bushes and bearings in any quantity.

CONTINUOUS CAST PHOSPHOR-BRONZE RODS AND TUBES

Round Solid Rod
from ½ in. dia. to 2½ in. dia.

Round Cored Rod
from 1 in. o.d. x ½ in. i.d. to 2½ in. o.d. x 2 in. i.d.

Minimum wall thickness ¼" all in 12 foot lengths.

NON-FERROUS AND HIGH DUTY IRON CASTINGS—FROM A FEW OUNCES TO 10 TONS IN QUANTITY OR ONE-OFF SPECIALS!

T. M. BIRKETT, BILLINGTON & NEWTON, LIMITED
HANLEY AND LONGPORT · STOKE-ON-TRENT · ENGLAND

Hanley, Phone: Stoke-on-Trent 22184/5/6/7. *Longport, Phone:* Newcastle, Staffs 51433/4.

BIRSO TRADE MARK BN

INDEX TO ADVERTISEMENTS

A

Acciaieria E Tubificio Di Brescia ... ... —
Allgemeine Elektricitäts-Gesellschaft ... ... —
Allmark Verken A.B. 29
Allis-Chalmers Hydraulic Division 30
Allmanna Svenska Electriska Aktiebolaget 9
Ansaldo San Giorgio, S.p.A. ... ... Inside Back Cover
Associated Electrical Industries (Manchester) Ltd. Outside Back Cover
Associated Electrical Industries (Rugby) Ltd. ... —
Associated Electrical Industries (Woolwich) Ltd. ... 32
Ateliers de Constructions Electriques de Della ... —
Atlas Copco, A.B. 47

B

Balfour, Beatty & Co. Ltd. 56
Bell, Theodore & Co. Ltd. 7
Birkett, T. M., Billington & Newton Ltd. 59
Bochumer Verein ... ... —
Bouchayer & Viallet ... ... —
Boving & Co. Ltd. 5
Boyles Bros. Drilling Co. Ltd. ... ... —
British Ropeway Engineering Co. Ltd. ... ... —
Brown, Boveri & Co. Ltd. 22
Bruce, Peebles & Co. Ltd. ... ... —
Bucyrus-Erie Co. Ltd. ... ... —
Buss, A.G. ... ... —
Butters Bros. & Co. Ltd. ... ... —

C

Canadian General Electric Co. Ltd. ... ... —
Canadian Vickers Ltd. 42
Canadian Wood Pipe & Tanks Ltd. 4
Ceretti & Tanfani Ropeway Co. Ltd. ... ... —
Charmilles Engineering Works Ltd. 55
Cockburns Ltd. ... ... —
Compagnie Industrielle de Travaux ... ... —
Consolidated Pneumatic Tool Co. Ltd. ... ... —

D

de Roll, Louis, Ironworks Ltd. 3
Dominion Engineering Co. Ltd. 51
Doulton Industrial Porcelains Ltd. 53
Drees & Co., G.m.b.H. 50

E

Eimco (Great Britain) Ltd. 49
Elliott Bros. ... ... —
English Electric Co. Ltd. ... ... Front Cover
English Steel Forge & Engineering Corporation Ltd. 20
Escher Wyss Ltd. ... ... —

F

Ferranti Ltd. ... ... —
Ferrum Montage ... ... —
Fischer, Ltd., George 15

G

Galileo Officine di Battaglia Terme 34
General Electric Co. Ltd. 43
Gilbert Gilkes & Gordon Ltd. ... ... —
Giovanola Freres, S.A ... ... —
Glenfield & Kennedy Ltd. 18
Gordon Valves, J., Ltd. 59

H

Harland Engineering Co. Ltd., The ... ... —
Hartley (Stoke-on-Trent) Ltd. ... ... —
Henderson, John M. & Co. Ltd. ... ... —
Hitachi Ltd. ... ... 24, 36 & 57
Huhn, G. 58
Hydraulics & Pneumatics Ltd. ... ... —
Hydraulic Service & Equipment Co. Ltd. ... ... —

I

International Engineering Co. Inc. ... ... —
International General Electric Co. ... ... —

J

Jonneret, S.A. Ateliers de Construction 54

K

Karlstads Mekaniska Werkstad, Akt. 35
Krupp, Fried. Maschinen- und Stahlbau 48
Kuljian Corporation, The 33
Kvaerner Brug A.S. 38

L

Leffel, James & Company, The 14
Lepper Transformatorenwerk August ... ... —
Le Materiel Electrique. S-W ... ... —

M

Magrini, S.p.A. ... ... —
Maschinenfabrik Augsburg-Nurnberg, A.G. 13
Maschinenfabrik B. Maier ... ... —
Mechans Ltd. 54
Micanite & Insulators Co. Ltd., The 40
Michell Bearings Ltd. ... ... —
Mitchell Construction Co., The 31
Mitsubishi Electric Manufacturing Co. 16

N

Neyrpic 23
Nippon Gaishi Kaisha Ltd. 11
Nuttall, E., Son & Co. (London) Ltd. 28
Nydqvist & Holm, A/B ... ... —

O

Oerlikon Engineering Company 10
Ossberger Turbinenfabrik ... ... —

P

Pirelli-General Cable Works Ltd. 6

R

Reyrolle, A. & Co. Ltd. ... ... Inside Front Cover
Ransomes & Rapier Ltd. 17
Riva Costruzioni Meccaniche 21
Rosenthal Isolatoren, G.m.b.H. ... ... —
Ruston Bucyrus Ltd. ... ... —

S

S.A. Ateliers De Secheron ... ... —
Sakai Iron Works Co. Ltd. 26
Salvi, A. & Co. ... ... —
Salzgitter Maschinen Aktiengesellschaft ... ... —
Savoisienne ... ... —
Scarpa & Magnano ... ... —
Siemens-Schuckertwerke, A.G. 44
Smith, Fredk. & Co. ... ... —
Soc. p. Az. Cementi Armati Ing. Mantelli ... ... —
Societa Nazionale Delle Officine Di Savigliano ... 25
Societe des Forges et Ateliers Du Creusot ... ... —
Steatite & Porcelain Products Ltd. 27
Sulzer Bros. (London) Ltd. 46
Svenska Metallverken, A/B ... ... —

T

Tampella OY ... ... —
Technoexport 37
Tees Side Bridge & Engineering Works Ltd. ... 56
Terni ... ... —
Tokyo Shibaura Electric Co. Ltd. 39
Torno, Giuseppe & Co. ... ... —
Tosi, Franco, S.p.A. ... ... —

V

Vereinigte Osterreichische Eisen- und Stahlwerke ... —
Victor Products Ltd. 8
Vevey Engineering Works Ltd. 19
Voith, J. M., G.m.b.H. 41

W

Waagner Biro AG. 16
White, R. & Sons (Engineers) Ltd. 58
Wood, Hugh & Co. Ltd. 52

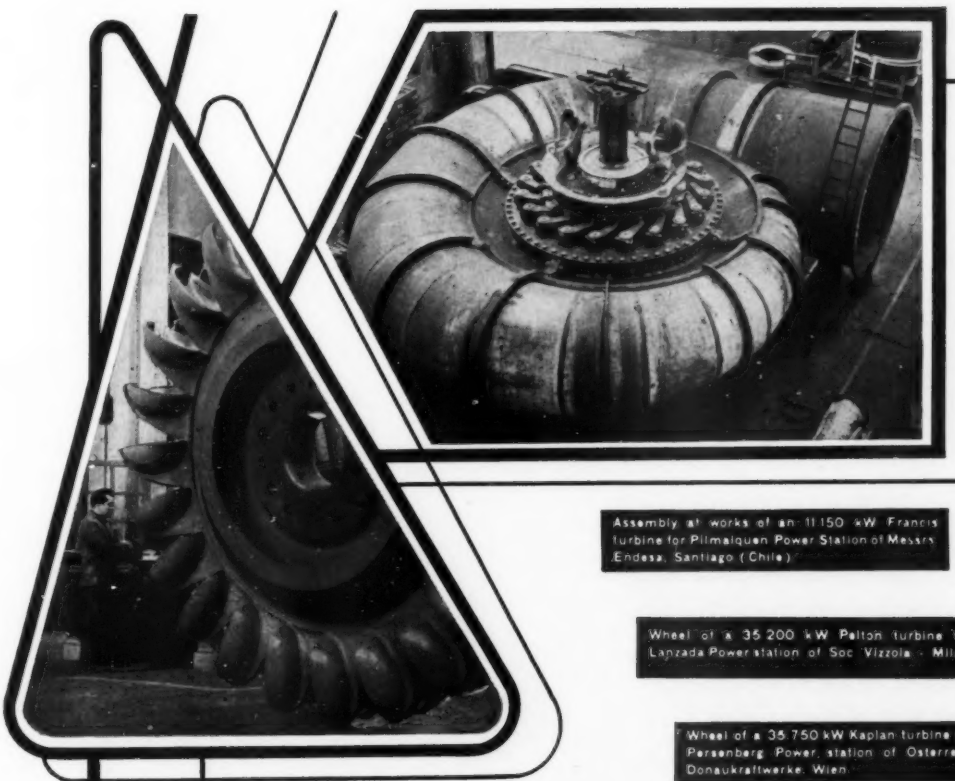
Y

Yorkshire Electric Transformer Co. Ltd ... ... —

LONDON: Published by TOTHILL PRESS LIMITED, Proprietors of WATER POWER, at 33 Tothill Street, Westminster, S.W.1. and Printed by W. & H. SMITH, LTD., Evesham, Worcestershire.

February, 1961

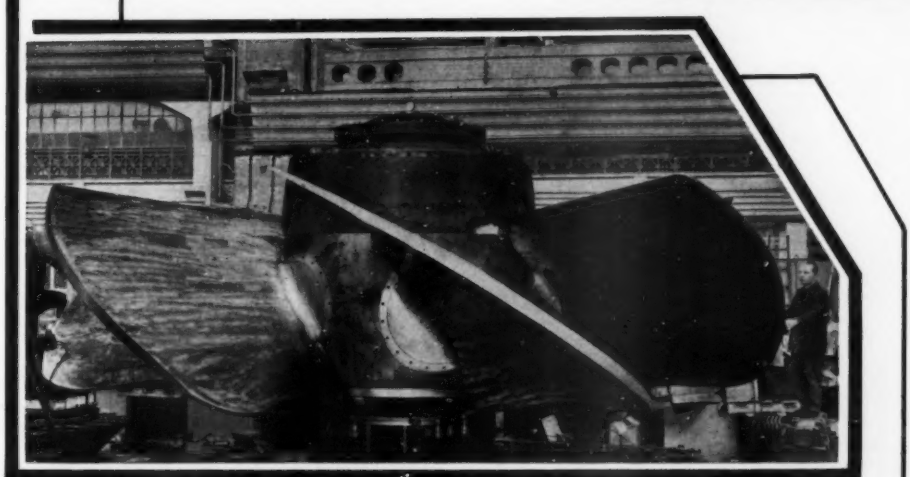
Complete hydro-electric plants



Assembly at works of an 11 150 kW Francis turbine for Pilmaiquen Power Station of Messrs Endesa, Santiago (Chile)

Wheel of a 35 200 kW Pelton turbine for Lanzada Power station of Soc. Vizzola - Milan

Wheel of a 35 750 kW Kaplan turbine for Ybbs Persenberg Power station of Osterreichische Donaukraftwerke, Wien

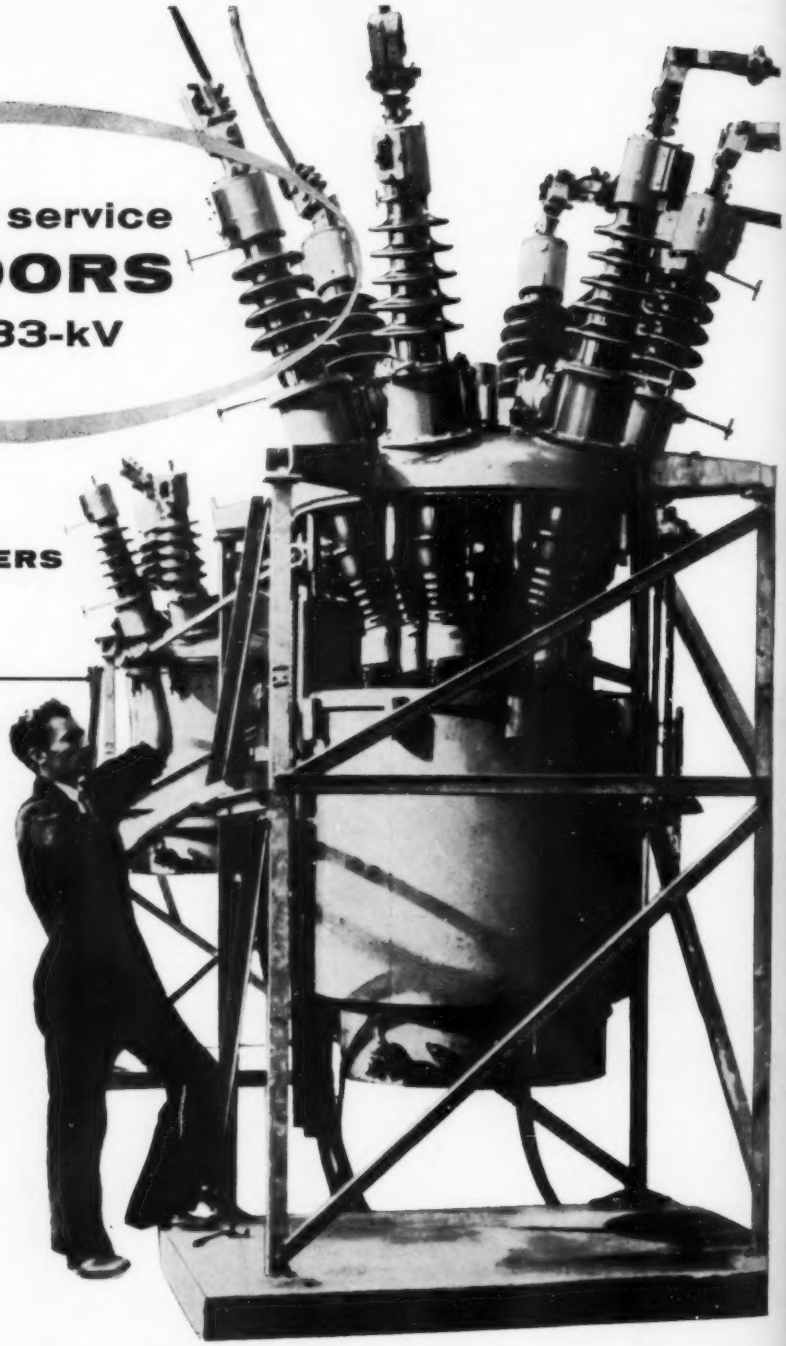


ANSALDO-SAN GIORGIO
GENOVA

For reliable service

OUTDOORS

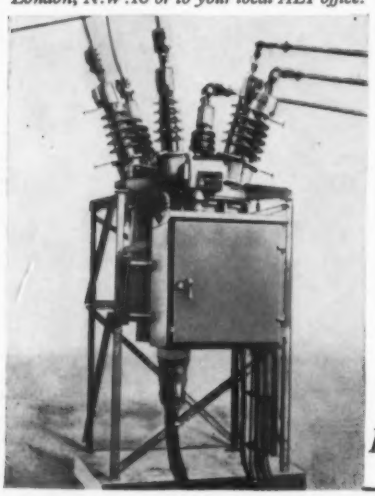
at 22 or 33-kV



TYPE JB 426
OIL CIRCUIT BREAKERS
BY AEI

These circuit breakers are of compact and robust construction, designed to give completely satisfactory service in the most onerous conditions.

For further details, write to AEI Switchgear Division, Willesden Works, Neasden Lane, London, N.W.10 or to your local AEI office.



Easy to install · Simple to maintain · Up to 1000 MVA

AEI

Associated Electrical Industries Ltd.

Switchgear Division

WILLESDEN, LONDON · TRAFFORD PARK, MANCHESTER · HIGHER OPENSHAW, MANCHESTER

FA/909